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Interactive Fortran Program to Calculate Thermophysical Properties of Six Fluids

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Interactive Fortran Program to Calculate Thermophysical Properties of Six Fluids

National Bureau of Standards

SEP 30 1982

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Interactive Fortran Program to Calculate Thermophysical

Properties of Six Fluids

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An interactive FORTRAN IV computer program is given for computing thermophysical properties of argon, ethylene, parahydrogen, nitrogen, nitrogen trifluoride, and oxygen. The program is designed for use with a computer terminal accessing a large computer in an interactive mode. The program provides prompting for selection of several options including: 1) choice of fluid, 2) choice of SI or engineering units, 3) choice of the single phase or liquid-vapor phase, and 4) a table of properties or a single value.

Properties are computed for the single phase region from input of two of the variables, temperature, pressure, and density. Values on the liquid-vapor boundary are computed from an entry of temperature or pressure. The program returns values for pressure, temperature, density, internal energy, enthalpy, entropy, specific heats at constant volume and pressure, and sound velocity. Viscosity, thermal conductivity, and dielectric constant are given for some of the fluids. Copies of the programs may be obtained from Office of Standard Reference Data, Attention: Reference Center, National Bureau of Standards, Washington, D.C. 20234.

Key words: argon; computer programs; density; enthalpy; equation of state; ethylene; hydrogen; nitrogen; nitrogen trifluoride; oxygen; specific heat at constant pressure; specific heat at constant volume.

1. Introduction

This report presents an interactive FORTRAN IV program for computing thermophysical properties of argon, ethylene, parahydrogen, nitrogen, nitrogen trifluoride, and oxygen. It is a companion publication to reference [1]. The properties found in this reference are computed from a standard set of equations and are presented in tables. References to the original works from which these correlations were abstracted are given in [1].

This is an interactive program which allows selection of several options including: 1) a choice of fluids, 2) SI or engineering units, 3) properties for the single phase or for the liquid-vapor boundary, and 4) a table of values or a single value. Properties of the homogeneous phase are computed at a single point from entry of any two of the three variables, temperature, pressure, and density. Properties on an isobar may be specified as well. Properties on the liquid-vapor boundary are computed from an entry of temperature or pressure.

2. Computer Routines

This program is a modification of program "Fluids Pack" by R. D. McCarty [2]. An early version of this type of program, which represents the thermophysical properties of several fluids, is program "GASP" (gas properties) by R. C. Hendricks, et al. [3]. The improvements in the experimental data used in the correlations, that have occurred since the publication of [3], have been incorporated in this report. Also, by retaining the same form of the equations for all fluids, the computer programming is much simplified and easier to use. Only the numerical constants, which are found in Appendix E, are changed from one fluid to the next.

A complete listing of the computer program is in Appendices D, E and F. The thermophysical properties produced by this system are the values given in reference [1]. The program is designed to be run interactively and provides instructions for its use and detects certain types of errors such

as entry of variables outside of the range of validity for the equation of state. The temperature and pressure range allowed for each fluid is automatically displayed when the fluid is first called. Since the basic equation of state for the fluids is semi-empirical in nature, the program should not be used outside the temperature and pressure range displayed for each fluid. Large errors in calculated properties can be expected outside the allowed ranges. An example of the program in use is presented in appendix B. Properties for computer program verification are given for each of the fluids in appendix C.

3. Thermodynamic and Related Properties

3.1 The Equation of State

The relation for computing pressure as a function of temperature and density is a 32-term modified Benedict-Webb-Rubin (MBWR) equation of state. Its versatility and adaptability to efficient computer technique make it appropriate for use with multiproperty fitting techniques, where deviations from the PVT surface and heat capacity or sound velocity data are minimized simultaneously, resulting in a more accurate model than would be the case if the PVT data alone were used. This technique has been described by R. D. McCarty [2,4]. Other advantages of the MBWR are: (1) accurate representation of the thermodynamic surface over wide ranges of temperature and pressure, (2) adaptability to least squares fitting methods using many different kinds of experimental data, and (3) convenience in correlating data from different sources.

The mathematical form of the MBWR is,

$$\begin{aligned}
 P = & \rho RT + \rho^2(G(1)T + G(2)T^{1/2} + G(3) + G(4)/T + G(5)/T^2) \\
 & + \rho^3(G(6)T + G(7) + G(8)/T + G(9)/T^2) \\
 & + \rho^4(G(10)T + G(11) + G(12)/T) + \rho^5(G(13)) \\
 & + \rho^6(G(14)/T + G(15)/T^2) + \rho^7(G(16)/T) \\
 & + \rho^8(G(17)/T + G(18)T^2) + \rho^9(G(19)/T^2) \\
 & + \rho^3(G(20)/T^2 + G(21)/T^3) \exp(\gamma\rho^2) \\
 & + \rho^5(G(22)/T^2 + G(23)/T^4) \exp(\gamma\rho^2) \\
 & + \rho^7(G(24)/T^2 + G(25)/T^3) \exp(\gamma\rho^2) \\
 & + \rho^9(G(26)/T^2 + G(27)/T^4) \exp(\gamma\rho^2) \\
 & + \rho^{11}(G(28)/T^2 + G(29)/T^3) \exp(\gamma\rho^2) \\
 & + \rho^{13}(G(30)/T^2 + G(31)/T^3 + G(32)/T^4) \exp(\gamma\rho^2)
 \end{aligned} \tag{1}$$

The nonlinear coefficient, γ , is defined generally as $\gamma = -1/\rho_C^2$, and is held constant during the fitting process to determine the linear coefficients $G(i)$.

Coefficients for each of the fluids are given in appendix E.

3.2 Two Phase Boundaries

3.2.1 Vapor Pressure

The temperature of the liquid-vapor boundary for each isobar in the tables is computed from a vapor pressure equation,

$$\ln P = \ln P_t + V_p(1)x + V_p(2)x^2 + V_p(3)x^3 + V_p(4)x^4 + V_p(5)x(1-x)^{V_p(6)} \quad (2)$$

where

$$x = (1 - T_t/T)/(1 - T_t/T_c) \quad (3)$$

The coefficients shown here as V_p are given in appendices D, E and F as VP since these appendices are listings of Fortran programs and subroutines. The same applies for other subscripted coefficients.

3.2.2 Vapor Densities at Coexistence

Densities of the vapor in coexistence with liquid, which are used to generate all the saturated densities given in the tables, are given by

$$\rho = \rho_c + (\rho_{tv} - \rho_c) \exp f(T) \quad (4)$$

and

$$f(T) = A(1) \ln x + \sum_{i=2}^4 A(i)(1 - x^{(i-5)/3}) + \sum_{i=5}^{13} A(i)(1 - x^{(i-4)/3} \quad (5)$$

where

$$x = (T - T_c)/(T_t - T_c) \quad (6)$$

3.2.3 Liquid Densities at Coexistence

The liquid density at coexistence is calculated from,

$$\rho = \rho_c + (\rho_{tl} - \rho_c) \exp f(T) \quad (7)$$

and

$$f(T) = A(14) \ln x + \sum_{i=15}^{17} A(i)(1 - x^{(i-18)/3}) + \sum_{i=18}^{20} A(i)(1 - x^{(i-17)/3}) \quad (8)$$

where x is defined in eq 6.

3.2.4 The Melting Line

The pressures at melting are given by,

$$P = P_x(1) + P_x(2)T^{P_x(3)} \quad (9)$$

3.3 Derived Thermodynamic Properties

The properties derived from the equation of state and ideal heat capacity are entropy, enthalpy, internal energy, specific heat at constant volume and at constant pressure, and sound velocity.

3.3.1 Entropy

The entropy is computed from

$$S(T, \rho) = S_0(T_0) + \int_{T_0}^T \left\{ C_p^0/T \right\} dT - R \ln(RT\rho/P_0) + \int_0^\rho \left\{ R/\rho - (1/\rho^2) \left(\frac{\partial P}{\partial T} \right)_\rho \right\} d\rho \quad (10)$$

3.3.2 Ideal Gas Specific Heat

The ideal gas specific heat, C_p^0 is computed from the following,

$$C_p^0/R = G_i(1)/T^3 + G_i(2)/T^2 + G_i(3)/T + G_i(4) + G_i(5)T + G_i(6)T^2 + G_i(7)T^3 + G_i(8)u^2 e^u / (e^u - 1)^2 \quad (11)$$

where,

$$u = G_i(9)/T \quad . \quad (12)$$

3.3.3 Reference State

The reference states S_0 and H_0 at $T = 298.15$ K (given below in table 1) are from Wagman, et al. [5], except for parahydrogen which is taken from Woolley, Scott, and Brickwedde [6], since reference [5] gives only the normal hydrogen values.

Table 1. Reference Values for Temperature, Entropy and Enthalpy.

The reference value for temperature is $T = 298.15$ K for all fluids. Values of S^0 and H^0 are from NBS TN 270-3 [5], except hydrogen [6].

	S^0 J/mol K	H^0 J/mol
argon	154.7335	6169.5
ethylene	219.451	10564.6
parahydrogen	130.407	8409.8
nitrogen	191.502	8669.0
nitrogen trifluoride	260.621	11828.0
oxygen	205.029	8680.1

3.3.4 Enthalpy

The enthalpy is computed from

$$H(T, \rho) = H^0 + (P - \rho RT)/\rho + \int_0^\rho \left\{ \frac{P}{\rho^2} - \frac{T}{\rho^2} \left(\frac{\partial P}{\partial T} \right)_\rho \right\} d\rho + \int_{T_0}^T C_p^0 dT \quad . \quad (13)$$

3.3.5 Internal Energy

The internal energy is,

$$E(T, \rho) = H(T, \rho) - P/\rho \quad . \quad (14)$$

3.3.6 Specific Heat at Constant Volume

The specific heat at constant volume is,

$$C_v(T, \rho) = C_p^0 - R - \int_0^\rho \left\{ \frac{T}{\rho^2} \left(\frac{\partial^2 P}{\partial T^2} \right)_\rho \right\} d\rho \quad . \quad (15)$$

3.3.7 Specific Heat at Constant Pressure

The specific heat at constant pressure is,

$$C_p(T, \rho) = C_v(T, \rho) + \left\{ \frac{T}{\rho^2} \left(\frac{\partial P}{\partial T} \right)_\rho^2 / \left(\frac{\partial P}{\partial \rho} \right)_T \right\} \quad . \quad (16)$$

3.3.8 Sound Velocity

The sound velocity can be computed as,

$$W(T, \rho) = \left\{ \frac{C_p}{C_v} \left(\frac{\partial P}{\partial \rho} \right)_T \right\}^{1/2} . \quad (17)$$

4. Transport Properties: Viscosity and Thermal Conductivity

Viscosity and thermal conductivity are given for argon, methane, nitrogen, and oxygen. The theory and discussion of the relations used here are from the work of Hanley, McCarty and Haynes [7]. The functional forms for viscosity and thermal conductivity are,

$$\eta = \eta_0(T) + \eta_1(T)\rho + \eta_2(\rho, T) \quad (18)$$

and

$$\lambda = \lambda_0(T) + \lambda_1(T)\rho + \lambda_2(\rho, T) + \lambda_c(\rho, T) . \quad (19)$$

The first terms of eqs (18) and (19) are the contributions of the dilute gas,

$$\eta_0(T) = \sum_{i=1}^9 G_v(i) T^{(4-i)/3} , \quad (20)$$

and

$$\lambda_0(T) = \sum_{i=1}^9 G_t(i) T^{(4-i)/3} .$$

The second terms in eqs (18) and (19) represent the contribution to the transport coefficients of the moderately dense gas.

$$\eta_1(T) = F_v(1) + F_v(2) F_v(3) - \ln(T/F_v(4))^2 ,$$

and

$$\lambda_1(T) = F_t(1) + F_t(2) F_t(3) - \ln(T/F_t(4))^2 . \quad (21)$$

The third terms in these equations are the contribution of the dense gas,

$$\eta_2(\rho, T) = \exp F(\rho, T) - \exp G(T) . \quad (22)$$

$$\begin{aligned} F(\rho, T) = & E_v(1) + E_v(2)H(\rho) + E_v(3)\rho^{0.1} + E_v(4)H(\rho)/T^2 \\ & + E_v(5)\rho^{0.1}/T^{1.5} + E_v(6)/T + E_v(7)H(\rho)/T \end{aligned} \quad (23)$$

$$G(T) = E_v(1) + E_v(2)/T \quad (24)$$

where

$$H(\rho) = \rho^{0.5} (\rho - E_v(8))/E_v(8) . \quad (25)$$

The functional forms of eqs (22), (23), (24) and (25) are used for the corresponding thermal conductivity equations with the coefficients E_t substituted for the E_v 's.

The last term of eq (19) is the critical enhancement term. Critical effects can be very large, especially in the range $(\rho - \rho_c)/\rho < 0.25$ and $(T - T_c)/T < 0.025$ and in fact, as the critical point is approached, this term may be larger than the sum of the other terms by several orders of magnitude. We include λ_c to give the proper behavior in the critical region and to produce a smooth transition from outside the critical region to within it.

5. Dielectric Constant

The dielectric constant defines the well known Clausius-Mossotti relation,

$$C_m = \frac{\epsilon-1}{\epsilon+2} \frac{1}{\rho} . \quad (26)$$

The C_m is represented by the empirical relation,

$$C_m = B_x(1) + B_x(2)\rho + B_x(3)\rho^2 + B_x(4)\rho^3 + B_x(5)T + B_x(6)P . \quad (27)$$

Coefficients are given for parahydrogen, nitrogen, and oxygen, but not for argon, ethylene, or nitrogen trifluoride. The coefficients of Stewart [8] for parahydrogen were modified to conform to eq (27). The data of Ely and Straty for nitrogen [9] were used in a fit of eq (27). The oxygen coefficients are from Younglove [10].

Although the range of the Clausius-Mossotti function for most liquids is small, the very high precision of the data require the terms of eq (27). The temperature and pressure terms are useful in fitting the compressed liquid states. The pressure term allows the flexibility which is useful in fluids with low compressibilities, usually found at low temperatures and high pressures [9].

6. Sample Calculations

In appendix C we have provided numerical values computed from the program (as given in appendices D, E and F). Values for the various properties are given for the saturated vapor and liquid at a pressure of 0.101325 MPa (1 atmosphere), and for the single phase at 35 MPa and 300 K. Failure to reproduce these numbers usually arises from using too few significant figures. This work was done using a 60 bit word. Use of double precision calculations may be necessary on computers with smaller word length.

7. Acknowledgments

We are indebted to the Office of Standard Reference Data of the National Bureau of Standards for its generous support, and to Robert D. McCarty on whose work this report is based.

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Appendix A. List of Symbols and Units.

Primary Thermophysical Quantities.

P, P_c, P_t	pressure, P at critical point, P at triple point, MPa
ρ, ρ_c	density, ρ at critical point, mol/dm ³
ρ_{tr}, ρ_{tv}	ρ of liquid at triple point, ρ of gas at triple point
T, T_c, T_t	temperature, T at critical point, T at triple point, K
C_p, C_p	specific heat at constant pressure, C_p of ideal gas, J/mol K
C_v, C_v	specific heat at constant volume, C_v for ideal gas, J/mol K
E	internal energy, J/mol
H, H°	enthalpy, reference value of H , J/mol
S, S°	entropy, reference value of S , J/mol K
W	sound velocity, m/s
η	viscosity, μ Pa s
λ	thermal conductivity, W/m K
ϵ	dielectric constant

Other Variables and Constants.

R	the gas constant, 8.31434 J/mol K
K_t	isothermal bulk modulus, (MPa) ⁻¹
M_r	molecular weight, g/mol
N_a	Avagadro's number, per mol
C_m	Clausius-Mossotti function
T_o	reference temperature, 298.15 K

Critical Point Values.

	P_c (MPa)	ρ_c (mol/dm ³)	T_c (K)
Ar	4.9058	13.41	150.86
C_2H_4	5.0404	7.650	282.34
H_2	1.28377	15.556	32.938
N_2	3.39908	11.21	126.26
Nf_3	4.4607	7.92	234.0
O_2	5.043	13.630	154.581

Appendix B. Sample Interactive Session

CALL,FLUIDS

FOR INFORMATION ON HOW TO USE THIS PROGRAM, ENTER "0" OTHERWISE, ENTER "1"
? 0

WHEN THE PROGRAM ASKS FOR A FLUID SELECTION, ENTER THE APPROPRIATE NUMBER. AN INAPPROPRIATE NUMBER WILL TERMINATE THE PROGRAM. WHEN IT ASKS FOR A PRESSURE, DENSITY, AND TEMPERATURE, ENTER ANY TWO OF OF THE THREE AND A ZERO FOR THE THIRD.
THE ORDER MUST BE P,D,T, AND ONE OF THE THREE MUST BE ZERO.
IF ALL THREE ARE ZERO THE PROGRAM ASKS FOR A NEW FLUID.

SELECT A FLUID BY ENTERING THE CORRESPONDING NUMBER
1=ARGON, 2=ETHYLENE, 3=PARA HYDROGEN,
4=NITROGEN, 5=NITROGEN TRIFLUORIDE, 6=OXYGEN 7=STOP
? 1

THE TEMPERATURE RANGE FOR ARGON IS 83.8 TO 400 K
WITH PRESSURES TO 100 MPa

FOR ENGINEERING UNITS ENTER "0", FOR METRIC ENTER "1"
? 1

FOR SATURATION PROPERTIES ENTER "0", FOR FLUID ENTER "1"
? 1

FOR A SINGLE POINT ENTER "0", FOR A TABLE ENTER "1"
? 1

ENTER A PRESSURE(MPa), A STARTING TEMPERATURE(K), A FINAL TEMPERATURE AND A TEMPERATURE INCREMENT AND IN THAT ORDER.

? 10 100 150 10

P MPA	T K	DEN MOL/L	E ==	H J/MOL/	S ==	CV ====	CP ==	SOUND M/S	VISC PA-S	COND MW/M-K E+6
10.000	100.000	33.744	-4271.	-3974.	59.6	20.4	44.0	800.	205.0	115.1
10.000	110.000	32.191	-3839.	-3529.	63.8	19.5	45.2	739.	162.7	102.9
10.000	120.000	30.525	-3396.	-3069.	67.8	18.8	46.9	672.	131.2	92.1
10.000	130.000	28.695	-2936.	-2587.	71.7	18.2	49.5	602.	106.4	81.8
10.000	140.000	26.609	-2447.	-2072.	75.5	17.6	54.1	526.	85.9	71.7
10.000	150.000	24.096	-1909.	-1494.	79.5	17.3	62.3	444.	67.9	61.7

ENTER A PRESSURE(MPa), A STARTING TEMPERATURE(K), A FINAL TEMPERATURE AND A TEMPERATURE INCREMENT AND IN THAT ORDER

? 0 0 0 0

SELECT A FLUID BY ENTERING THE CORRESPONDING NUMBER
1=ARGON, 2=ETHYLENE, 3=PARA HYDROGEN,
4=NITROGEN, 5=NITROGEN TRIFLUORIDE, 6=OXYGEN 7=STOP
? 8

EXIT.

Appendix C. Properties for Computer Program Verification

ARGON PROPERTIES.

T K	DEN MOL/L	E == J/MOL	H == J/MOL	S ==== J/MOL-K	CV ====	CP ====	SOUND M/S	VISC PA-S	COND MW/M-K E+6
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SATURATED VAPOR AT 0.101325 MPA.

87.2815 .1446 1038.7 1739.4 128.63 13.22 22.76 170.7 7.3 5.9

SATURATED LIQUID AT 0.101325 MPA.

87.2815 34.8946 -4708.7 -4705.8 54.82 22.27 44.73 814.4 260.3 128.3

SINGLE PHASE AT 35 MPA AND 300 K.

300.0000 13.6426 1830.3 4395.8 100.94 14.07 32.82 445.8 39.5 36.9

ETHYLENE PROPERTIES

T K	DEN MOL/L	E == J/MOL	H == J/MOL	S ==== J/MOL-K	CV ====	CP ====	SOUND M/S	VISC PA-S	COND MW/M-K E+6
--------	--------------	---------------	---------------	-------------------	------------	------------	--------------	--------------	-----------------------

SATURATED VAPOR AT 0.101325 MPA.

169.4093 .0744 4180.6 5541.6 197.66 27.13 36.89 252.3

SATURATED LIQUID AT 0.101325 MPA.

169.4093 20.2449 -8001.8 -7996.8 117.73 38.22 67.92 1310.1

SINGLE PHASE AT 35 MPA AND 300 K.

300.0000 15.8136 -504.6 1708.7 151.74 41.68 70.79 868.6

HYDROGEN PROPERTIES

T K	DEN MOL/L	E == J/MOL	H == J/MOL	S ==== J/MOL-K	CV ====	CP ====	SOUND M/S	VISC PA-S	COND MW/M-K ==	DIEL
--------	--------------	---------------	---------------	-------------------	------------	------------	--------------	--------------	----------------------	------

SATURATED VAPOR AT 0.101325 MPA.

20.27 .664 229.5 382.0 60.40 13.31 24.68 354. 1.00404

SATURATED LIQUID AT 0.101325 MPA.

20.27 35.118 -518.9 -516.0 16.11 11.43 19.49 1100. 1.22981

SINGLE PHASE AT 35 MPA AND 300 K.

300.00 11.517 5837.0 8875.8 81.58 22.23 31.12 1609. 1.07174

NITROGEN PROPERTIES.

T K	DEN MOL/L	E == J/MOL	H == J/MOL	S ==== J/MOL-K	CV ====	CP ====	SOUND M/S	VISC PA-S	COND MW/M-K ==	DIEL
--------	--------------	---------------	---------------	-------------------	------------	------------	--------------	--------------	----------------------	------

SATURATED VAPOR AT 0.101325 MPA.

77.36 .164 1548.0 2163.5 151.54 21.59 31.45 175. 5.3 7.6 1.00217

SATURATED LIQUID AT 0.101325 MPA.

77.36 28.863 -3404.3 -3400.8 79.54 27.82 57.80 939. 151.6 133.7 1.43356

SINGLE PHASE AT 35 MPA AND 300 K.

300.00 11.756 4623.9 7601.1 138.73 22.29 38.11 514. 28.7 48.0 1.16337

NITROGEN TRIFLUORIDE PROPERTIES.

T K	DEN MOL/L	E == J/MOL	H == J/MOL	S ==== J/MOL-K	CV ====	CP =====	SOUND M/S	VISC PA-S	COND MW/M-K
--------	--------------	---------------	---------------	-------------------	------------	-------------	--------------	--------------	----------------

E+6

SATURATED VAPOR AT 0.101325 MPA.
144.1082 .0879 3575.7 4728.5 227.83 29.65 39.49 144.1

SATURATED LIQUID AT 0.101325 MPA.
144.1082 21.6563 -6832.5 -6827.8 147.66 40.30 72.20 757.5

SINGLE PHASE AT 35 MPA AND 300 K.
300.0000 14.3859 3299.9 5732.9 197.40 50.03 80.58 412.4

OXYGEN PROPERTIES.

T K	DEN MOL/L	E == J/MOL	H == J/MOL	S ==== J/MOL-K	CV ====	CP =====	SOUND M/S	VISC PA-S	COND MW/M-K	DIEL ==
--------	--------------	---------------	---------------	-------------------	------------	-------------	--------------	--------------	----------------	------------

E+6

SATURATED VAPOR AT 0.101325 MPA.
90.19 .140 1811.5 2535.6 169.58 21.72 31.34 178. 6.7 8.5 1.00166

SATURATED LIQUID AT 0.101325 MPA.
90.19 35.658 -4265.5 -4262.7 94.19 29.54 54.22 905. 194.7 151.8 1.48704

SINGLE PHASE AT 35 MPA AND 300 K.
300.00 13.742 4233.0 6780.0 150.97 22.62 41.95 442. 34.7 46.4 1.17222

Appendix D. Program Listing for Program Fluids

```

PROGRAM FLUIDS(INPUT,OUTPUT)
DIMENSION G(32),VP(9)
COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TPP,TUL,TLL,PUL,DCC
COMMON/CONT/IF
COMMON/CRIT/EM,EOK,RM,TC,DC,X,PC,SIG
COMMON/DIEL/BX(6),PX(6)
1000 FORMAT(* FOR INFORMATION ON HOW TO USE THIS PROGRAM, ENTER "0" *
      A * OTHERWISE, ENTER "1"*)
      PRINT 1000
      IP=3
      PRINT 1210
      READ 1010,I
      IF(I.EQ.0)CALL INFO
      PRINT 1210
1010 FORMAT(I1)
110 PRINT 1020
      PRINT 1030
1020 FORMAT(* SELECT A FLUID BY ENTERING THE CORRESPONDING NUMBER*)
1030 FORMAT(* 1=ARGON,           2=ETHYLENE,           3=PARA HYDROGEN,
      A   *,/,* 4=NITROGEN,      5=NITROGEN TRIFLUORIDE, 6=OXYGEN*
      B   ,*           7=STOP*)
      READ *,IF
      PRINT 1210
      GO TO(1,2,3,4,5,6,999),IF
1 CALL DATA AR
      GO TO 120
2 CALL DATA C3
      GO TO 120
3 CALL DATA PH2
      GO TO 120
4 CALL DATA N2
      GO TO 120
5 CALL DATA NF3
      GO TO 120
6 CALL DATA O2
      GO TO 120
120 PRINT 1040
1040 FORMAT(* FOR ENGINEERING UNITS ENTER "0", FOR METRIC ENTER "1"*)
      READ 1010,IU
      PRINT 1210
      PRINT 1050
1050 FORMAT(* FOR SATURATION PROPERTIES ENTER "0", FOR FLUID ENTER *
      A *"1"*)
      READ 1010,IC
      PRINT 1210
      PRINT 1060
1060 FORMAT(* FOR A SINGLE POINT ENTER "0", FOR A TABLE ENTER "1"*)
      READ 1010,IV
      PRINT 1210
160 IF(IC.EQ.0)GO TO 240
      IF(IV.EQ.1)GO TO 330
170 IF(IU.EQ.0)GO TO 180
      PRINT 1080
      READ *,P,D,T
      PRINT 1210
      GO TO 190
180 PRINT 1070
1070 FORMAT(* ENTER PRESSURE(PSIA), DENSITY(LB/CU FT), AND TEMPERATURE*
      A *(F)*)
      READ *,P,D,T
      PRINT 1210
      P=(P/14.695949)*.101325

```

```

D=D*16.01846371/EM
IF(T.EQ.0.0)GO TO 190
T=(T-32.)/1.8+273.15
190 IF(P.LE.0.0)GO TO 220
1080 FORMAT(* ENTER PRESSURE(MPA), DENSITY(MOL/L), AND TEMPERATURE(K)*)
IF(D.LE.0.0)GO TO 210
IF(T.LE.0.0)GO TO 200
GO TO 170
200 IF(P.LE.0.OR.D.LE.0.0)GO TO 110
T=FIND T(P,D)
CALL LIMITS(P,T,IL)
IF(IL.LE.0)GO TO 170
GO TO 230
210 IF(T.LE.0.OR.P.LE.0)GO TO 110
CALL LIMITS(P,T,IL)
IF(IL.LE.0)GO TO 170
D=FIND D(P,T)
GO TO 230
220 IF(D.LE.0.0.OR.T.LE.0)GO TO 110
P=FIND P(D,T)
CALL LIMITS(P,T,IL)
IF(IL.LE.0)GO TO 170
230 CALL REPRO(P,D,T,IU,IV,IC,IP,TF,DELT)
GO TO 170
240 PRINT 1090
1090 FORMAT(* FOR SATURATED LIQUID ENTER "0", FOR VAPOR ENTER "1"*)
READ 1010,IP
PRINT 1210
IF(IV.EQ.1)GO TO 330
PRINT 1095
1095 FORMAT(* TO ENTER WITH TEMPERATURE ENTER "0", FOR PRESSURE "1"*)
READ 1010,II
PRINT 1210
IF(II.EQ.1)GO TO 290
250 IF(IU.EQ.1)GO TO 260
1100 FORMAT(* ENTER A TEMPERATURE IN DEGREES F*)
PRINT 1100
READ *,TI
PRINT 1210
T=(TI-32.)/1.8+273.15
IF(T.LE.0.0)GO TO 110
GO TO 270
260 PRINT 1110
1110 FORMAT(* ENTER A TEMPERATURE(K)*)
READ *,T
PRINT 1210
270 IF(T.LT..0000001)GO TO 110
IF(T.GT.TCC.OR.T.LT.TTP)GO TO 280
P=VPN(T)
IF(IP.EQ.0)P=P+.00001
D=FIND D(P,T)
CALL RE PRO(P,D,T,IU,IV,IC,IP,TF,DELT)
GO TO 250
280 PRINT 1120,TTP,TCC,(TTP-273.15)*1.8+32.,(TCC-273.15)*1.8+32.
1120 FORMAT(* FOR SATURATION *,F6.2,* < TEMP < *,F6.2,* K*,/,
A * OR *,F7.2,* < TEMP < *,F7.2,* F*)
GO TO 250
290 IF(IU.EQ.1)GO TO 300
PRINT 1130
1130 FORMAT(* ENTER A PRESSURE IN LB/SQ IN*)
READ *,PI
PRINT 1210
IF(PI.LE.0.0)GO TO 110
P=(PI/14.695949)*.101325
GO TO 310

```

```

300 PRINT 1140
1140 FORMAT(* ENTER A PRESSURE(MPA)*)
  READ *,PI
  PRINT 1210
  IF(PI.LE.0.0)GO TO 110
  P=PI
310 IF(P.GT.PCC.OR.P.LT.PTP)GO TO 320
  T=FIND TV(P)
  P=VPN(T)
  IF(IP.EQ.0)P=P+.00001
  D=FIND D(P,T)
  CALL RE PRO(P,D,T,IU,IV,IC,IP,TF,DELT)
  GO TO 290
320 PRINT 1150, PTP,PCC
1150 FORMAT(* YOUR INPUT PRESSURE IS OUTSIDE THE RANGE OF SATURATION*
  A * PRESSURES/* FOR THIS FLUID. TRIPLE POINT=*,F6.5,* MPA,*
  B * CRITICAL POINT=*,F6.3,* MPA/* TRY AGAIN*)
  GO TO 290
330 IF(IC.EQ.1)GO TO 370
  IF(IU.EQ.1)GO TO 340
  PRINT 1160
1160 FORMAT(* ENTER A STARTING TEMPERATURE, A FINAL TEMPERATURE*
  A /* AND A TEMPERATURE INCREMENT, IN DEGREES F AND IN THAT ORDER*)
  READ *,TS,TF,DELT
  PRINT 1210
  IF(DELT.LE.0.0)GO TO 110
  TS=(TS-32.)/1.8+273.15
  TF=(TF-32.)/1.8+273.15
  DELT=DELT/1.8
  IF(TS.LT.TTP.OR.TS.GT.TCC)GO TO 360
  IF(TF.LT.TTP.OR.TF.GT.TCC)GO TO 360
  GO TO 350
340 PRINT 1170
1170 FORMAT(* ENTER A STARTING TEMPERATURE, A FINAL TEMPERATURE*
  1/* AND A TEMPERATURE INCREMENT IN KELVINS AND IN THAT ORDER*)
  READ *,TS,TF,DELT
  PRINT 1210
  IF(DELT.LE.0.0)GO TO 110
  IF(TS.LT.TTP.OR.TS.GT.TCC)GO TO 360
  IF(TF.LT.TTP.OR.TF.GT.TCC)GO TO 360
350 T=TS
  P=VPN(T)
  IF(IP.EQ.0)P=P+.00001
  D=FIND D(P,T)
  CALL RE PRO(P,D,T,IU,IV,IC,IP,TF,DELT)
  GO TO 330
360 PRINT 1180,TTP,TCC,(TTP-273.15)*1.8+32.,(TCC-273.15)*1.8+32
1180 FORMAT(* FOR SATURATION, *,F6.2,* < TEMP < *,F6.2,* K*,/,
  A ,13X,*OR, *,F7.1,* < TEMP < *,F7.1,* F. TRY AGAIN.*)
  GO TO 330
370 IF(IU.EQ.1)GO TO 380
  PRINT 1190
1190 FORMAT(* ENTER PRESSURE(PSIA), STARTING TEMPERATURE(F), FINAL *
  A *TEMPERATURE(F)/* AND A TEMPERATURE INCREMENT, IN THAT ORDER*)
  READ *,PI,TS,TF,DELT
  PRINT 1210
  IF(DELT.LE.0.0)GO TO 110
  P=(PI/14.695949)*.101325
  T=(TS-32.)/1.8+273.15
  TF=(TF-32.)/1.8+273.15
  DELT=DELT/1.8
  CALL LIMITS(P,T,IL)
  IF(IL.LE.0)GO TO 370
  CALL LIMITS(P,TF,IL)
  IF(IL.LE.0)GO TO 370

```

```

GO TO 390
380 PRINT 1200
1200 FORMAT(* ENTER A PRESSURE(MPA), A STARTING TEMPERATURE(K), A *
1*FINAL TEMPERATURE AND A*/* TEMPERATURE INCREMENT*
2* AND IN THAT ORDER, TO RESTART PROGRAM ENTER "0,0,0,0"*)
READ *,PI,TS,TF,DELT
PRINT 1210
IF(DELT.LE.0.0)GO TO 110
T=TS
P=PI
CALL LIMITS(P,T,IL)
IF(IL.LE.0)GO TO 370
CALL LIMITS(P,TF,IL)
IF(IL.LE.0)GO TO 370
390 D=FIND D(P,T)
CALL RE PRO(P,D,T,IU,IV,IC,IP,TF,DELT)
GO TO 370
999 CONTINUE
1210 FORMAT(* *)
END

```

```

SUBROUTINE REPRO(P,D,T,IU,IV,IC,IP,TF,DELT)
DIMENSION G(32),VP(9)
COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TPP,TUL,TLL,PUL,DCC
COMMON/CONT/IF
COMMON/CRIT/EM,EOK,RM,TC,DC,X,PC,SIG
COMMON/CPID/GI(11),GH(11),GL(11)
COMMON/HAN/CR,TCI
N=500
IF(IV.EQ.0)TF=T-1.
IF(IU.EQ.0)GO TO 100
PRINT 1000
PRINT 1010
PRINT 1020
GO TO 110
100 PRINT 1000
PRINT 1030
PRINT 1040
110 CONTINUE
DO 210 I=1,N
IF(I.EQ.1)GO TO 120
D=FIND D(P,T)
120 H=ENTHAL(P,D,T)
E=H-1000.*P/D
S=ENTROP(D,T)
W=SOUND(D,T)
CPP=CP(D,T)
CVV=CV(D,T)
IF(IU.EQ.0)GO TO 160
IF(IF.EQ.4.OR.IF.EQ.6) GO TO 150
C IF=4 FOR N2, IF=6 FOR O2.
IF(IF.EQ.1) GO TO 140
C IF=1 FOR AR
IF(IF.EQ.3) GO TO 130
C IF=3 FOR H2
C IF=2 FOR C2H4, IF=5 FOR NF3
PRINT 2000, P,T,D,E,H,S,CVV,CPP,W
GO TO 200
130 EPS=DIEL(P,D,T)
PRINT 2010, P,T,D,E,H,S,CVV,CPP,W,EP
GO TO 200
140 TH=THERM(D,T)*1000.
V=VISC(D,T)
PRINT 2020, P,T,D,E,H,S,CVV,CPP,W,V,TH

```

```

GO TO 200
150 V=VISC(D,T)
TH=THERM(D,T)*1000.
EPS=DIEL(P,D,T)
PRINT 2030, P,T,D,E,H,S,CVV,CPP,W,V,TH,EPS
GO TO 200
160 H=H/(2.324445*EM)
E=E/(2.324445*EM)
S=S/(4.184001*EM)
CPP=CPP/(4.184001*EM)
CVV=CVV/(4.184001*EM)
W=W*3.280840
PO=(P/.101325)*14.695949
DO=D*EM/16.01846371
TO=T*1.8-459.67
IF(IF.EQ.4.OR.IF.EQ.6) GO TO 190
IF(IF.EQ.1) GO TO 180
IF(IF.EQ.3) GO TO 170
PRINT 3000, PO,TO,DO,E,H,S,CVV,CPP,W
GO TO 200
170 EPS=DIEL(P,D,T)
PRINT 3010, PO,TO,DO,E,H,S,CVV,CPP,W,EPS
GO TO 200
180 V=VISC(D,T)*.067196897
TH=THERM(D,T)*.578176
PRINT 3020, PO,TO,DO,E,H,S,CVV,CPP,W,V,TH
GO TO 200
190 V=VISC(D,T)*.067196897
TH=THERM(D,T)*.578176
EPS=DIEL(P,D,T)
PRINT 3030, PO,TO,DO,E,H,S,CVV,CPP,W,V,TH,EPS
200 T=T+DELT
IF(T.GT.TF+.01)GO TO 220
IF(IC.EQ.0)P=VPN(T)
IF(IP.EQ.0)P=P+.000001
210 CONTINUE
220 CONTINUE
PRINT 1000
1000 FORMAT(* *)
RETURN
1010 FORMAT(3X,*P*,5X,*T*,6X,*DEN*,5X,*E*,6X,*H*,6X,*S*,4X,*CV*,4X,
A *CP*,3X,*SOUND*,2X,*VISC*,2X,*COND*,2X,*DIEL*)
1020 FORMAT(3X,*MPA*,3X,*K*,6X,*MOL/L*,2X,*== J/MOL ==*,2X,"==== ",
A "J/MOL-K ==",2X,*M/S*,3X,"PA-S",1X,"MW/M-K",2X,*==*,/,61X,*E+6*)
1030 FORMAT(3X,*P*,5X,*T*,7X,*DENS*,3X,*E*,8X,*H*,5X,*S*,5X,*CV*,
A 4X,*CP*,2X,*SOUND*,1X,*VISC*,2X,*COND*,2X,*DIEL*)
1040 FORMAT(3X,*PSIA*,2X,*F*,7X,*LB/*,3X,*==== BTU/ ===*,1X,*=====*,,
A * BTU/ =====*,2X,*F/S*,3X,*LB/*,2X,*BTU/*,2X,*==*,/,17X,*CU FT*,,
B 6X,*LB*,14X,"LB-F",13X,"FT-S",1X,"FT-HR-F",/,62X,"E+7")
2000 FORMAT(F7.3,F8.3,F7.3,2F7.0,F6.1,F5.1,F6.1,F6.0)
2010 FORMAT(F7.3,F8.3,F7.3,2F7.0,F6.1,F5.1,F6.1,F6.0,13X,F8.5)
2020 FORMAT(F7.3,F8.3,F7.3,2F7.0,F6.1,F5.1,F6.1,F6.0,F6.1,F6.1)
2030 FORMAT(F7.3,F8.3,F7.3,2F7.0,F6.1,F5.1,F6.1,F6.0,F6.1,F6.1,F8.5)
3000 FORMAT(F7.1,F8.3,F7.3,2F7.1,3F6.3,F6.0)
3010 FORMAT(F7.1,F8.3,F7.3,2F7.1,3F6.3,F6.0,11X,F8.5)
3020 FORMAT(F7.1,F8.3,F7.3,2F7.1,3F6.3,F6.0,F5.2,F6.4)
3030 FORMAT(F7.1,F8.3,F7.3,2F7.1,3F6.3,F6.0,F5.2,F6.4,F8.5)
END

```

Appendix E. Data Subroutines

```

SUBROUTINE DATA AR
DIMENSION G(32),VP(9)
DIMENSION GV(9),GT(9),FV(4),FT(4),EV(8),ET(8)
DIMENSION A(20)
COMMON/SEN/BETA,XO,DELTA,E1, E2, AGAM
COMMON/SATC/A,DTPV
COMMON/CRIT/ EM, EOK, RM, TC, DC, X , PC, SIG
COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TPP,TUL,TLL,PUL,DCC
COMMON/DATA1/GV,GT,FV,FT,EV,ET
COMMON/CPID/GI(11),GH(11),GL(11)
COMMON/ISP/N,NW,NWW
COMMON/FIXPT/T0,SO,HO
COMMON/DIEL/BX(6),PX(6)
NWW=0
PRINT 100
100 FORMAT(* THE TEMPERATURE RANGE FOR ARGON IS 83.8 TO 400 K*
1/* WITH PRESSURES TO 100 MPa*)
N=0 $ NW=1
EM=39.948 $ EOK=152.8 $ RM=3.669E-08 $ TC=150.725
DC=0.533 $ X=1.7124 $ PC=4.8619 $ SIG=3.297
XO=0.183 $ BETA=0.355 $ DELTA=4.352 $ E1=2.27 $ E2=0.287
AGAM=1.190
C
C **** ARGON COEFFICIENTS FOR MBWR EQN
C
G( 1)= -.65697312940E-04
G( 2)= .18229578010E-01
G( 3)= -.36494701410E+00
G( 4)= .12320121070E+02
G( 5)= -.86135782740E+03
G( 6)= .79785796910E-05
G( 7)= -.29114891100E-02
G( 8)= .75818217580E+00
G( 9)= .87804881690E+03
G(10)= .14231459890E-07
G(11)= .16741461310E-03
G(12)= -.32004479090E-01
G(13)= .25617663720E-05
G(14)= -.54759349410E-04
G(15)= -.45050320580E-01
G(16)= .20132546530E-05
G(17)= -.16789412730E-07
G(18)= .42073292710E-04
G(19)= -.54442129960E-06
G(20)= -.80048550110E+03
G(21)= -.13193042010E+05
G(22)= -.49549239300E+01
G(23)= .80921321770E+04
G(24)= -.98701040610E-02
G(25)= .20204415620E+00
G(26)= -.16374172050E-04
G(27)= -.70389441360E-01
G(28)= -.11543245390E-07
G(29)= .15559901170E-05
G(30)= -.14921785360E-10
G(31)= -.10013560710E-08
G(32)= .29339632160E-07
GAMMA=-.0055542372
C
C **** ARGON COEFFICIENTS FOR VAPOR PRESSURE
C
VP(1)= 3.4151115519 $ VP(2)= 1.1910812519

```

```

VP(3)= -.3407632334   $ VP(5)= .89555855251
VP(6)= 1.5             $ VP(9)= .06890606625
VP(7)= 83.80           $ VP(8)= 150.86
VP(4)= 0.0

```

```

C
C **** ARGON COEFFICIENTS FOR SATURATED LIQUID AND VAPOR DENSITIES.
C

```

```

A( 1)= -.270262923777E+02
A( 2)= .131040241866E+00
A( 3)= -.267486438128E+01
A( 4)= .300176804406E+02
A( 5)= -.875899149326E+02
A( 6)= -.408267436456E+02
A( 7)= .104268066451E+03
A( 8)= -.671278555379E+02
A( 9)= .151002935701E+02
A(10)= -.331243536637E+02
A(11)= .633146212581E+02
A(12)= -.427149706899E+02
A(13)= .100599900030E+02
A(14)= .137682084900E+02
A(15)= -.664630363191E-01
A(16)= .133368782730E+01
A(17)= -.144371463244E+02
A(18)= .601938472000E+02
A(19)= -.230888463887E+02
A(20)= .465318358887E+01

```

```

C
C **** ARGON COEFFICIENTS FOR IDEAL GAS CP.
C

```

```

GI(1)=GI(2)=GI(3)=0
GI(4)=GI(9)=2.5
GI(5)=GI(6)=GI(7)=0
GI(8)=0
GI(10)=GI(11)=0.0

```

```

C
C **** ARGON COEFFICIENTS FOR FIRST TERM OF VISCOSITY EQN.
C **** VISCOSITY IN MICRO-PA*S, DENSITY IN G/CC.
C

```

```

GV(1)= .61145472787E+04 $ GV(2)= -.10394390312E+05
GV(3)= .67594614619E+04 $ GV(4)= -.22536509380E+04
GV(5)= .42593950138E+03 $ GV(6)= -.47252671093E+02
GV(7)= .31795275425E+01 $ GV(8)= -.11629083780E+00
GV(9)= .18043010592E-02

```

```

C
C **** ARGON COEFFICIENTS FOR FIRST TERM OF THERMAL CONDUCTIVITY EQN.
C **** THERMAL CONDUCTIVITY IN WATT/(M*K), DENSITY IN G/CC.
C

```

```

GT(1)= .62777703742E+01 $ GT(2)= -.96096376637E+01
GT(3)= .58887549191E+01 $ GT(4)= -.18920926320E+01
GT(5)= .34886571437E+00 $ GT(6)= -.38016786193E-01
GT(7)= .25207283167E-02 $ GT(8)= -.91098744478E-04
GT(9)= .13990842942E-05

```

```

C
C **** ARGON COEFFICIENTS FOR SECOND TERM OF VISCOSITY EQN.
C

```

```

FV(1)= .14653652433E+00 $ FV(2)= -.77487424965E-01
FV(3)= .14000000000E+01 $ FV(4)= .15280000000E+03

```

```

C
C **** ARGON COEFFICIENTS FOR SECOND TERM OF THERMAL CONDUCTIVITY EQN.
C

```

```

FT(1)= .24142103270E-01 $ FT(2)= .75696234255E-02
FT(3)= .10000000000E+01 $ FT(4)= .15280000000E+03

```

```

C
C **** ARGON COEFFICIENTS FOR THIRD TERM OF VISCOSITY EQN.

```

```

C
EV(1)= -.12313579086E+02 $ EV(2)= .20694685712E+00
EV(3)= .16029145122E+02 $ EV(4)= .11717461351E+04
EV(5)= -.56995898780E+03 $ EV(6)= .40136071933E+02
EV(7)= .39870122403E+02 $ EV(8)= .53700000000E+00
C
C ***** ARGON COEFFICIENTS FOR THIRD TERM OF THERMAL CONDUCTIVITY EQN.
C
ET(1)= -.33327027332E+02 $ ET(2)= 0.0
ET(3)= .30694859971E+02 $ ET(4)= 0.0
ET(5)= .22956551674E+04 $ ET(6)= -.35559415848E+03
ET(7)= 0.0 $ ET(8)= 1.0
C
C ***** ARGON COEFFICIENTS FOR MELTING EQUATION.
C
PX(1)= -.210562165E+03
PX(2)= .177760527E+00
PX(3)= .159817868E+01
C
C THE FOLLOWING ARE CONSTANTS USED IN THE COMPUTATION OF PROPERTIES FOR
C ARGON
C
R=.08205616*.101325
T0=298.15 $ S0=154.7335 $ H0=6196.5
GI(10)=H0-HI(T0)
GI(11)=S0-SI(T0)
DTP=.3540027619188E+02
DTPV=.1029227022329
TCC=VP(8)
PCC=VPN(TCC)
PTP=VP(9)
TTP=VP(7)
TUL=400.
TLL=TTP
PUL=100.
DCC=13.41
RETURN
END

C
C
C SUBROUTINE DATA C3
C COEFFICIENTS FOR ETHYLENE
DIMENSION A(20)
DIMENSION G(32),VP(9)
DIMENSION GV(9),GT(9),FV(4),FT(4),EV(8),ET(4)
COMMON/CPID/GI(11),GH(11),GL(11)
COMMON/CRIT/ EM, EOK, RM, TC, DC, X , PC, SIG
COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TTP,TUL,TLL,PUL,DCC
COMMON/DATA1/GV,GT,FV,FT,EV,ET
COMMON/ISP/N,NW,NWW
COMMON/SATC/A,DTPV
COMMON/DIEL/BX(6),PX(6)
N=0
PRINT 100
100 FORMAT(* THE TEMPERATURE RANGE FOR ETHYLENE IS 104 TO 400K*
1/* WITH PRESSURES TO 40 MPA*)
C
C ***** ETHYLENE COEFFICIENTS FOR MBWR EQN
C
G( 1)= -.2146684366683E-02
G( 2)= .1791433722534E+00
G( 3)= -.3675315603930E+01
G( 4)= .3707178934669E+03
G( 5)= -.3198282566709E+05
G( 6)= .5809379774732E-04
G( 7)= -.7895570824899E-01

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```

G( 8)= .1148620375835E+02
G( 9)= .2713774629193E+05
G(10)= -.8647124319107E-05
G(11)= .1617727266385E-01
G(12)= -.2731527496271E+01
G(13)= -.2672283641459E-03
G(14)= -.4752381331990E-02
G(15)= -.6255637346217E+01
G(16)= .4576234964434E-03
G(17)= -.7534839269320E-05
G(18)= .1638171982209E-01
G(19)= -.3563090740740E-03
G(20)= -.1833000783170E+05
G(21)= -.1805074209985E+07
G(22)= -.4794587918874E+03
G(23)= .3531948274957E+07
G(24)= -.2562571039155E+01
G(25)= .1044308253292E+03
G(26)= -.1695303363659E-01
G(27)= -.1710334224958E+03
G(28)= -.2054114462372E-04
G(29)= .6727558766661E-02
G(30)= -.1557168403328E-06
G(31)= -.1229814736077E-04
G(32)= .4234325938573E-04
GAMMA=-.0172

```

```

C
C ***** ETHYLENE COEFFICIENTS FOR VAPOR PRESSURE
C
    VP(1)= 8.2095798      $  VP(2)= 4.315424145
    VP(3)= -1.692585975    $  VP(5)= 3.446501098
    VP(6)= 1.5              $  VP(9)= .00012129514
    VP(7)= 103.986         $  VP(8)= 282.3428
    VP(4)= -.1976495575

```

```

C
C ***** ETHYLENE COEFFICIENTS FOR SATURATED LIQUID AND VAPOR DENSITIES.
C

```

```

A( 1)= -.609621515594E+02
A( 2)= .203185312702E-01
A( 3)= -.925441265813E+00
A( 4)= .243630795888E+02
A( 5)= -.854745622888E+03
A( 6)= .123927868183E+04
A( 7)= -.142710711789E+04
A( 8)= .837358670405E+03
A( 9)= .432203696552E+03
A(10)= -.137917541161E+04
A(11)= .126858600124E+04
A(12)= -.571552321713E+03
A(13)= .106012234360E+03
A(14)= -.479047060183E+01
A(15)= .151381345283E-01
A(16)= -.403456079445E+00
A(17)= .508683920225E+01
A(18)= -.246711997987E+02
A(19)= .980030915247E+01
A(20)= -.216846516122E+01

```

```

C
C ***** ETHYLENE COEFFICIENTS FOR IDEAL GAS HEAT CP.
C

```

```

GI(1)=.5603615762E+6
GI(2)=-.2141069802E+5
GI(3)=.2532008897E+3
GI(4)=.3554495281E+1
GI(5)=-.9951927478E-2

```

```

GI(6)=.5108931070E-4
GI(7)=-.1928667482E-7
GI(8)=-.2061703241E+2
GI(9)=.3E+4
GI(10)=GI(11)=0
TO=298.15 $ SO=219.451 $ HO=10564.6
GI(10)=HO-HI(TO)
GI(11)=SO-SI(TO)
C
C ***** ETHYLENE COEFFICIENTS FOR MELTING EQUATION.
C
PX(1)= -.357923875E+03
PX(2)= .245332143E-01
PX(3)= .206450000E+01

C THE FOLLOWING CONSTANTS USED IN THE COMPUTATION OF PROPERTIES FOR
C ETHYLENE

GAMMA=-.0172
R=.08205616*.101325
DTP=23.34296694034
DTPV=.1425455127094E-03
EM=28.054
TCC=VP(8)
PCC=VPN(TCC)
PTP=VP(9)
TTP=VP(7)
TUL=400.
TLL=TTP
PUL=40.
DCC=7.650
RETURN
END

C
SUBROUTINE DATA P H2
DIMENSION G(32),VP(9),GI(11),GH(11),GL(11)
DIMENSION GV(9),GT(9),FV(4),FT(4),EV(8),ET(8)
DIMENSION A(20)
COMMON/SATC/A,DTPV
COMMON/CPID/GI,GH,GL
COMMON/CRIT/ EM, EOK, RM, TC, DC, X , PC, SIG
COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TTP,TUL,TLL,PUL,DCC
COMMON/DATA1/GV,GT,FV,FT,EV,ET
COMMON/DIEL/BX(6),PX(6)
COMMON/ISP/N,NW,NWW
N=1
PRINT 100
100 FORMAT(* THE TEMPERATURE RANGE FOR HYDROGEN IS 13.8 TO 400 K*
1/* WITH PRESSURES TO 120 MPA*)
C
C ***** PARAHYDROGEN COEFFICIENTS FOR MBWR EQUATION.
C
G( 1)= .4675528393416E-04
G( 2)= .4289274251454E-02
G( 3)= -.5164085596504E-01
G( 4)= .2961790279801E+00
G( 5)= -.3027194968412E+01
G( 6)= .1908100320379E-05
G( 7)= -.1339776859288E-03
G( 8)= .3056473115421E-01
G( 9)= .5161197159532E+01
G(10)= .1999981550224E-07
G(11)= .2896367059356E-04
G(12)= -.2257803939041E-02
G(13)= -.2287392761826E-06
G(14)= .2446261478645E-05

```

```

G(15)= -.1718181601119E-03
G(16)= -.5465142603459E-07
G(17)= .4051941401315E-09
G(18)= .1157595123961E-06
G(19)= -.1269162728389E-08
G(20)= -.4983023605519E+01
G(21)= -.1606676092098E+02
G(22)= -.1926799185310E-01
G(23)= .9319894638928E+00
G(24)= -.3222596554434E-04
G(25)= .1206839307669E-03
G(26)= -.3841588197470E-07
G(27)= -.4036157453608E-05
G(28)= -.1250868123513E-10
G(29)= .1976107321888E-09
G(30)= -.2411883474011E-13
G(31)= -.4127551498251E-13
G(32)= .8917972883610E-12
GAMMA=-.0041

```

```

C
C ***** PARAHYDROGEN COEFFICIENTS FOR VAPOR PRESSURE
C
    VP(1)= 3.05300134164    $  VP(2)= 2.80810925813
    VP(3)= -0.655461216567   $  VP(5)= 1.59514439374
    VP(6)= 1.5814454428     $  VP(9)= 0.0070420875
    VP(7)= 13.8              $  VP(8)= 32.938
    VP(4)= 0.0

```

```

C
C ***** PARAHYDROGEN COEFFICIENTS. SATURATED LIQUID AND VAPOR DENSITIES.
C

```

```

A( 1)= .916617720187E+02
A( 2)= -.179492524446E+00
A( 3)= .454671158395E+01
A( 4)= -.658499589788E+02
A( 5)= .734466804535E+03
A(. 6)= -.682501045175E+03
A( 7)= .631783674710E+03
A( 8)= -.539408873282E+03
A( 9)= .430923811783E+03
A(10)= -.300295738811E+03
A(11)= .156567165346E+03
A(12)= -.504103608225E+02
A(13)= .720706926514E+01
A(14)= -.123944440318E+03
A(15)= .140334800142E+01
A(16)= -.211023804313E+02
A(17)= .173254622817E+03
A(18)= -.444294580871E+03
A(19)= .138699365355E+03
A(20)= -.235774161015E+02

```

```

C
C ***** PARAHYDROGEN COEFFICIENTS FOR IDEAL GAS CP.
C      FOR TEMPERATURES > 140 K.
C

```

```

GH( 1)= .5262185164597E+08
GH( 2)= -.1487906248823E+07
GH( 3)= .1601391392264E+05
GH( 4)= -.8031235938946E+02
GH( 5)= .2307407941873E+00
GH( 6)= -.3176386248370E-03
GH( 7)= .1643857271214E-06
GH( 8)= .9230816464058E+01
GH( 9)= .3E+4
GH(10)= 0.0
GH(11)= 0.0

```

```

C
C ***** PARAHYDROGEN COEFFICIENTS FOR IDEAL GAS CP.
C      FOR TEMPERATURES 40 < T < 140 K.
C
C      GL( 1)= .2905965792270E+06
C      GL( 2)= -.2831103639248E+05
C      GL( 3)= .1050424877391E+04
C      GL( 4)= -.1535751501769E+02
C      GL( 5)= .1218941696566E+00
C      GL( 6)= -.2599406479908E-04
C      GL( 7)= -.1288757333406E-05
C      GL( 8)= .1717441975231E+06
C      GL( 9)= .3E+4
C      GL(10)= 0.0
C      GL(11)= 0.0
C      TO=298.15 $ SO=130.407 $ HO=8409.8
C      HO AND SO TAKEN FROM WOOLLEY, SCOTT, AND BRICKWEDDE
C      NBS RP 1932, PAGE 387. VALUES FOR PARAHYDROGEN.
C      GH(10)=HO-HI(TO)
C      GL(10)=GH(10)
C      GH(11)=SO-SI(TO)
C      GL(11)=GH(11)
C
C
C ***** PARAHYDROGEN COEFFICIENTS FOR MELTING PRESSURE.
C      FOR TEMPERATURES < 22 K :
C
C      PX(1)= -21.281484395
C      PX(2)= .125746643
C      PX(3)= 1.955
C
C ***** PARAHYDROGEN COEFFICIENTS FOR MELTING PRESSURE.
C      FOR TEMPERATURES > 22 K :
C
C      PX(4)= -26.5289115
C      PX(5)= .248578596
C      PX(6)= 1.764739
C
C ***** PARAHYDROGEN COEFFICIENTS FOR DIELECTRIC CONSTANT.
C
C      BX(1)= .20245443E-02
C      BX(2)= .37171832E-06
C      BX(3)= -.92085013E-08
C      BX(4)= -.34065328E-11
C      BX(5)= .0
C      BX(6)= .0
C
C      THE FOLLOWING ARE CONSTANTS USED IN THE COMPUTATION OF PROPERTIES FOR
C      PARAHYDROGEN
C
C      R=.08205616*.101325
C      DTP=.3821428945438E+02
C      DTPV=.6322296353698E-01
C      EM=2.01594
C      TCC=VP(8)
C      PCC=VPN(TCC)
C      PTP=VP(9)
C      TTP=VP(7)
C      TUL=400.
C      TLL=TTP
C      PUL=120.
C      DCC=15.556
C      RETURN
C      END

```

C

```
SUBROUTINE DATA N2
DIMENSION G(32),VP(9)
DIMENSION GV(9),GT(9),FV(4),FT(4),EV(8),ET(8)
DIMENSION A(20)
COMMON/CRIT/ EM, EOK, RM, TC, DC, X , PC, SIG
COMMON/SATC/A,DTPV
COMMON/DATA1/GV,GT,FV,FT,EV,ET
COMMON/SEN/BETA,XO,DELTA,E1, E2, AGAM
COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TPP,TUL,TLL,PUL,DCC
COMMON/CPID/GI(11),GH(11),GL(11)
COMMON/ISP/N,NW,NWW
COMMON/DIEL/BX(6),PX(6)
NWW=0
PRINT 100
100 FORMAT(* THE RANGE OF TEMPERATURE FOR NITROGEN IS 63.15 TO 1900K*
1/* WITH PRESSURES TO 1000 MPa*)
N=0 $ NW=1
EM=28.016 $ EOK=118. $ RM=3.933E-08 $ TC=126.24
DC=0.3139 $ X=1.67108 $ PC=3.443 $ SIG=3.54
XO=0.164 $ BETA=0.355 $ DELTA=4.352 $ E1=2.17 $ E2=0.287
AGAM=1.190
```

C

C ***** NITROGEN COEFF FOR MBWR EQUATION

C

```
G( 1)= .138029747465691E-03
G( 2)= .108450650134880E-01
G( 3)= -.247132406436209E+00
G( 4)= .345525798080709E+01
G( 5)= -.427970769066595E+03
G( 6)= .106491156699760E-04
G( 7)= -.114086707973499E-02
G( 8)= .144490249728747E-04
G( 9)= .187145756755327E+04
G(10)= .821887688683079E-08
G(11)= .236099049334759E-03
G(12)= -.514480308120135E-01
G(13)= .491454501366803E-05
G(14)= -.115162716239893E-03
G(15)= -.716803724664983E-01
G(16)= .761666761949981E-05
G(17)= -.113093006621295E-06
G(18)= .373683116683089E-04
G(19)= -.203985150758086E-06
G(20)= -.171966200898966E+04
G(21)= -.121305519974777E+05
G(22)= -.988139914142789E+01
G(23)= .561988689351085E+04
G(24)= -.182304396411845E-01
G(25)= -.259982649847705E+00
G(26)= -.419189342315742E-04
G(27)= -.259640667053023E-01
G(28)= -.125868320192119E-07
G(29)= .104928659940046E-05
G(30)= -.545836930515201E-10
G(31)= -.767451167059717E-09
G(32)= .593123287099439E-08
GAMMA=-.0056
```

C

C ***** NITROGEN COEFF FOR VAPOR PRESS.

C

```
VP(1)= 5.1113192094 $ VP(2)=.6482667539
VP(3)= -.15108730916 $ VP(5)=.74028493342
VP(6)= 1.5 $ VP(9)=.012462975
VP(7)= 63.15 $ VP(8)= 126.26
```

```

VP(4)= 0.0
C
C ***** N2 COEF FOR SAT LIQUID AND VAPOR DENS.
C
A( 1)= -.158453465507E+02
A( 2)= .419136911423E-01
A( 3)= -.101965371660E+01
A( 4)= .134763743799E+02
A( 5)= -.109930399087E+03
A( 6)= .925518835497E+02
A( 7)= -.956233831320E+02
A( 8)= .100104366710E+03
A( 9)= -.701857937398E+02
A(10)= .900076998647E+01
A(11)= .286981120347E+02
A(12)= -.216767601780E+02
A(13)= .496558226471E+01
A(14)= .218307928477E+02
A(15)= -.126493309807E+00
A(16)= .241544188633E+01
A(17)= -.245256871794E+02
A(18)= .935925207124E+02
A(19)= -.360938251632E+02
A(20)= .757453271989E+01
C
C ***** N2 COEF FOR IDEAL GAS CP.
C
GI(1)= -0.735210401157252E 03
GI(2)= 0.342239980411978E 02
GI(3)= -0.557648284567620E 00
GI(4)= 0.350404228308756E 01
GI(5)= -0.173390185081005E-04
GI(6)= 0.174650849766463E-07
GI(7)= -0.356892033544348E-11
GI(8)= 0.100538722808834E 01
GI(9)= 0.335340610000000E 04
GI(10)=GI(11)=0.0
C
C ~**** N2 COEF FOR 1ST TERM OF VISC
C      VISC IN MICRO PA*S, DENSITY IN G/CC
C
GV(1)= -.18224240000E+05 $ GV(2)= .19915327374E+05
GV(3)= -.91542324494E+04 $ GV(4)= .23255484059E+04
GV(5)= -.36307214228E+03 $ GV(6)= .36457506811E+02
GV(7)= -.22261880817E+01 $ GV(8)= .78053904895E-01
GV(9)= -.11894029104E-02
C
C ***** N2 COEF FOR 1ST TERM THERM. COND.
C      THERM. COND. IN WATT/(M*K), DENS. IN G/CC.
C
GT(1)= -.20029573972E+02 $ GT(2)= .49765746684E+01
GT(3)= .80188959378E+01 $ GT(4)= -.55022716888E+01
GT(5)= .15363738965E+01 $ GT(6)= -.22974737257E+00
GT(7)= .19360547346E-01 $ GT(8)= -.85677385768E-03
GT(9)= .15564670935E-04
C
C ***** N2 COEF FOR 2ND TERM VISC.
C
FV(1)= -.11217739623E+00 $ FV(2)= .32912317244E-01
FV(3)= .14000000000E+01 $ FV(4)= .11800000000E+03
C
C ***** N2 COEF FOR 2ND TERM THERM. COND.
C
FT(1)= .53875666637E-01 $ FT(2)= .61027911104E-02
FT(3)= .12000000000E+01 $ FT(4)= .11800000000E+03

```

```

C
C ***** N2 COEF FOR 3RD. TERM VISC.
C
C     EV(1)= -.12128154129E+02  $  EV(2)= .57156092139E+00
C     EV(3)= .16094611148E+02  $  EV(4)= .36954086158E+04
C     EV(5)= -.80889801180E+03  $  EV(6)= .68464435640E+02
C     EV(7)= -.21241135912E+01  $  EV(8)= .31500000000E+00
C
C ***** N2 COEF FOR 3RD TERM OF THERM. COND.
C
C     ET(1)= -.38613291627E+02  $  ET(2)= .0
C     ET(3)= .37201743333E+02  $  ET(4)= .0
C     ET(5)= -.39013509079E+02  $  ET(6)= -.31826109485E+02
C     ET(7)= .0                 $  ET(8)= 1.0
C
C ***** N2 COEF FOR MELTING.
C
C     PX(1)= -.160000281E+03
C     PX(2)= .938575502E-01
C     PX(3)= .179500000E+01
C
C ***** N2 COEF FOR DIEL. CONST.
C
C     BX(1)= .43993836E-02
C     BX(2)= .18932096E-05
C     BX(3)= 0.
C     BX(4)= -.31450178E-08
C     BX(5)= -.28592703E-06
C     BX(6)= -.44666034E-07
C
C THE FOLLOWING ARE CONSTANTS USED IN THE COMPUTATION OF PROPERTIES FOR
C NITROGEN
C
R=(8.20539E-2)*.101325
TO=298.15 $ SO=191.502 $ HO=8669.0
GI(10)=HO-HI(TO)
GI(11)=SO-SI(TO)
DTP=.3097717741477E+2
DTPV=.242822085710E-1
TCC=VP(8)
PCC=VPN(TCC)
PTP=VP(9)
TTP=VP(7)
TUL=1900.
TLL=TTP
PUL=1000.
DCC=11.21
RETURN
END

SUBROUTINE DATA NF3
DIMENSION G(32),VP(9),A(20)
COMMON/CRIT/ EM, EOK, RM, TC, DC, X, PC, SIG
COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TTP,TUL,TLL,PUL,DCC
COMMON/SATC/A,DTPV
COMMON/CPID/GI(11),GH(11),GL(11)
COMMON/DIEL/BX(6),PX(6)
PRINT 100
100 FORMAT(* THE RANGE OF TEMPERATURE FOR NITROGEN TRIFLUORIDE IS*
      A ,/* 66.36 K TO 500 K, WITH PRESSURES TO 50 MPA.*)
C
C ***** NITROGEN TRIFLUORIDE COEFFICIENTS FOR MBWR EQUATION.
C
G( 1)= .1774353868E-02
G( 2)= -.5409379418E-01
G( 3)= .3976634466E+00
G( 4)= -.5209476694E+02
G( 5)= -.3286322888E+04

```

G(6)= -.5990517411E-04
G(7)= .9217525601E-01
G(8)= -.4848977075E+02
G(9)= -.4235892691E+06
G(10)= -.9824248063E-06
G(11)= .5432235989E-02
G(12)= -.1462388500E+01
G(13)= -.3366180440E-03
G(14)= .2801374599E-01
G(15)= .8435288597E+00
G(16)= -.1324421452E-02
G(17)= .1875604377E-04
G(18)= .2959643991E-01
G(19)= -.7009976870E-03
G(20)= .4365820912E+06
G(21)= -.1111397536E+07
G(22)= .2411866612E+04
G(23)= .3179136276E+06
G(24)= .6166849090E+01
G(25)= .4260854720E+01
G(26)= .1090598789E-01
G(27)= -.3340951059E+01
G(28)= .8597429644E-05
G(29)= .1240544214E-03
G(30)= .1286224248E-07
G(31)= -.8941104276E-07
G(32)= .3353054595E-05
GAMMA=-.0056

C
C ***** NITROGEN TRIFLUORIDE COEFFICIENTS FOR VAPOR PRESSURE.
C
VP(1)= 11.593879492 \$ VP(2)= 9.6548502312
VP(3)= -2.8727732815 \$ VP(5)= 7.3112441673
VP(6)= 1.5 \$ VP(9)= .18537827E-6
VP(7)= 66.36 \$ VP(8)= 234.0
VP(4)= -1.37977007

C
C ***** NITROGEN TRIFLUORIDE COEFF. FOR SATURATED LIQUID AND VAPOR DENSITIES
C

A(1) = .131285181636E+03
A(2) = -.226998555536E+01
A(3) = .384708389498E+02
A(4) = -.309827268239E+03
A(5) = -.635348526635E+03
A(6) = .926979028357E+03
A(7) = .371498011259E+03
A(8) = -.182291654470E+04
A(9) = .105592403853E+04
A(10) = .121673895344E+04
A(11) = -.207208928323E+04
A(12) = .113463394710E+04
A(13) = -.226642137140E+03
A(14) = .105087295173E+01
A(15) = -.131686474246E-02
A(16) = .390141331900E-01
A(17) = -.587796597975E+00
A(18) = .400900521017E+01
A(19) = -.203385386977E+01
A(20) = .400434364424E+00

C
C ***** NITROGEN TRIFLUORIDE COEFFICIENTS FOR IDEAL GAS CP.
C

GI(1)= .7427518245951E+06
GI(2)= -.4389825372134E+05
GI(3)= .1012629224351E+04*

```

GI(4)= -.7140693612211E+01
GI(5)= .5481339146452E-01
GI(6)= -.7677196006769E-04
GI(7)= .4203630864340E-07
GI(8)= -.6328752997967E+00
GI(9)= .3E+4
GI(10)=GI(11)=0.0

```

```

C
C ***** NITROGEN TRIFLUORIDE COEFFICIENTS FOR MELTING.
C

```

```

PX(1)= -.190939971E+03
PX(2)= .813750194E-01
PX(3)= .185000000E+01

```

```

C THE FOLLOWING ARE CONSTANTS USED IN THE COMPUTATION OF PROPERTIES FOR
C NITROGEN TRIFLUORIDE

```

```

C**- THE TO,HO,SO IDEAL GAS REFERENCE VALUES ARE FROM
C TO,HO,SO ARE FROM NBS TN 270-3('68), "SELECTED VALUES OF CHEMICAL
C THERMODYNAMIC PROPERTIES" WAGMAN ET AL., PP 70
    TO=298.15 $ SO=260.621 $ HO=11828.

```

```

    GI(10)=HO-HI(TO)
    GI(11)=SO-SI(TO)
    EM=71.019
    R=.0820568*.101325
    PTP=.185425E-06
    DTP=26.32
    DTPV=.33612E-08
    TTP=66.36
    PCC=4.4607
    DCC=7.92
    TCC=234.0
    TC=234.0
    VP(8)=TC
    DC=7.92
    PUL= 50.
    TUL=500.
    TLL=TTP
    RETURN
    END

```

SUBROUTINE DATA 02

```

DIMENSION G(32),VP(9),GI(11),GH(11),GL(11)
DIMENSION GV(9),GT(9),FV(4),FT(4),EV(8),ET(8)
DIMENSION A(20)
COMMON/SATC/A,DTPV
COMMON/DATA1/GV,GT,FV,FT,EV,ET
COMMON/SEN/BETA,XO,DELTA,E1, E2, AGAM
COMMON/CRIT/ EM, EOK, RM, TC, DC, X , PC, SIG
COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TTT,TUL,TLL,PUL,DCC
COMMON/ISP/N,NW,NWW
COMMON/CPID/GI,GH,GL
COMMON/DIEL/BX(6),PX(6)
N=0 $ NW=1 $ NWW=0
PRINT 100

```

```

100 FORMAT(* THE TEMPERATURE RANGE FOR OXYGEN IS 54.359 TO 400 K*
1/* WITH PRESSURES TO 120 MPa*)
    XO=0.183 $ BETA=0.355 $ DELTA=4.352 $ E1=2.21 $ E2=0.287
    EM=31.9988 $ EOK=113.0 $ RM=3.8896E-08$ TC=154.575
    DC=0.4362 $ X=2.210636 $ PC=5.0429 $ SIG=3.437
    AGAM = 1.190

```

```

C
C ***** OXYGEN COEFFICIENTS FOR MBWR EQUATION.
C

```

```

G( 1)= -.4365859650E-04
G( 2)= .2005820677E-01
G( 3)= -.4197909916E+00
G( 4)= .1878215317E+02

```

```

G( 5)= -.1287473398E+04
G( 6)= .1556745888E-05
G( 7)= .1343639359E-03
G( 8)= -.2228415518E+00
G( 9)= .4767792275E+03
G(10)= .4790846641E-07
G(11)= .2462611107E-03
G(12)= -.1921891680E-01
G(13)= -.6978320847E-06
G(14)= -.6214145909E-04
G(15)= -.1860852567E-01
G(16)= .2609791417E-05
G(17)= -.2447611408E-07
G(18)= .1457743352E-04
G(19)= -.1726492873E-06
G(20)= -.2384892520E+03
G(21)= -.2301807796E+05
G(22)= -.2790303526E+01
G(23)= .9400577575E+04
G(24)= -.4169449637E-02
G(25)= .2008497853E+00
G(26)= -.1256076520E-04
G(27)= -.6406362964E-01
G(28)= -.2475580168E-08
G(29)= .1346309703E-05
G(30)= -.1161502470E-10
G(31)= -.1034699798E-08
G(32)= .2365936964E-07
GAMMA=-.0056

```

```

C **** OXYGEN COEFFICIENTS FOR VAPOR PRESSURE.
C
```

```

VP(1)= 7.568956      $ VP(2)= 5.004836
VP(3)= -2.13746      $ VP(5)= 3.454481
VP(6)= 1.514          $ VP(9)= .0001479953
VP(7)= 54.359          $ VP(8)= 154.581
VP(4)= 0.0

```

```

C **** OXYGEN COEFFICIENTS FOR SATURATED LIQUID AND VAPOR DENSITIES.
C
```

```

A( 1)= .581394753076E+02
A( 2)= -.490241196133E-01
A( 3)= .168328893252E+01
A( 4)= -.325161223398E+02
A( 5)= .550300989872E+03
A( 6)= -.510968506115E+03
A( 7)= .315091559049E+03
A( 8)= -.232566659258E+02
A( 9)= -.488425479359E+02
A(10)= -.150624217523E+03
A(11)= .280441603851E+03
A(12)= -.176693896861E+03
A(13)= .403247747449E+02
A(14)= .252198688365E+01
A(15)= -.136098316472E-01
A(16)= .282316159403E+00
A(17)= -.286645905341E+01
A(18)= .617024212284E+01
A(19)= -.810220795462E+00
A(20)= -.279601068969E+00

```

```

C **** OXYGEN COEFFICIENTS FOR IDEAL GAS CP.
C
```

```

GI(1)= -0.498199853711943E 04
GI(2)= 0.230247779995218E 03

```

```

GI(3)= -0.345565323510732E 01
GI(4)= 0.352187677367116E 01
GI(5)= -0.435420216024420E-04
GI(6)= 0.134635345013162E-07
GI(7)= 0.162059825959105E-10
GI(8)= 0.103146851572565E 01
GI(9)= 0.223918105000000E 04
GI(10)=GI(11)=0.0
C
C **** OXYGEN COEFFICIENTS FOR FIRST TERM OF VISCOSITY EQN.
C VISCOSITY IN MICRO-PA*S, DENSITY IN G/CC.
C
GV(1)= -.97076378593E+04 $ GV(2)= .82801254201E+04
GV(3)= -.24668758803E+04 $ GV(4)= .21324360243E+03
GV(5)= .37851049522E+02 $ GV(6)= -.10487216090E+02
GV(7)= .11134441304E+01 $ GV(8)= -.53676093757E-01
GV(9)= .10279379641E-02
C
C **** OXYGEN COEFFICIENTS FOR FIRST TERM OF THERMAL CONDUCTIVITY EQN.
C THERMAL CONDUCTIVITY IN WATTS/(M*K), DENSITY IN G/CC.
C
GT(1)= -.20395052193E+03 $ GT(2)= .24088141709E+03
GT(3)= -.12014175183E+03 $ GT(4)= .32954949190E+02
GT(5)= -.54244239598E+01 $ GT(6)= .54734865540E+00
GT(7)= -.32854821539E-01 $ GT(8)= .10753572103E-02
GT(9)= -.14610986820E-04
C
C **** OXYGEN COEFFICIENTS FOR SECOND TERM OF VISCOSITY EQN.
C
FV(1)= .43526515153E+00 $ FV(2)= -.20361263878E+00
FV(3)= .14000000000E+01 $ FV(4)= .10000000000E+03
C
C **** OXYGEN COEFFICIENTS FOR SECOND TERM OF THERMAL CONDUCTIVITY EQN.
C
FT(1)= .30600000000E-01 $ FT(2)= .27850000000E-01
FT(3)= .11200000000E+01 $ FT(4)= .10000000000E+03
C
C **** OXYGEN COEFFICIENTS FOR THIRD TERM OF VISCOSITY EQN.
C
EV(1)= -.14454972110E+02 $ EV(2)= -.31421728994E+00
EV(3)= .18201161468E+02 $ EV(4)= .27390429525E+03
EV(5)= -.27498956948E+04 $ EV(6)= .24340689667E+03
EV(7)= .11911504104E+03 $ EV(8)= .43500000000E+00
C
C **** OXYGEN COEFFICIENTS FOR THIRD TERM OF THERMAL CONDUCTIVITY EQN.
C
ET(1)= -.21520741137E+02 $ ET(2)= .0
ET(3)= .16799504261E+02 $ ET(4)= .0
ET(5)= -.29944878721E+04 $ ET(6)= .47350508788E+03
ET(7)= .0 $ ET(8)= 1.0
C
C **** OXYGEN COEFFICIENTS FOR MELTING
C
PX(1)= -.267226854E+03
PX(2)= .227606348E+00
PX(3)= .176900000E+01
C
C **** OXYGEN COEFFICIENTS FOR DIELECTRIC CONSTANT.
C
BX(1)= .39608100E-02
BX(2)= .29700000E-06
BX(3)= -.41300000E-07
BX(4)= 0.0
BX(5)= 0.0
BX(6)= -.21400000E-07

```

C THE FOLLOWING ARE CONSTANTS USED IN THE COMPUTATION OF PROPERTIES FOR
C OXYGEN

C TO,HO,SO ARE FROM NBS TN270 (SELECTED VALUES OF CHEM THERMO PROPS)
C PAGE 11. COMPUTED IDEAL GAS PROPS CONFORM TO JANAF(NSRDS-NBS37(71))
TO=298.15 \$ SO=205.029 \$ HO=8680.1
GI(10)= HO-HI(TO)
GI(11)= SO-SI(TO)
R=8.20539E-2*.101325
DTP=.4081997364372E+02
DTPV=.3318894767078E-03
TCC=VP(8)
PCC=VPN(TCC)
PTP=VP(9)
TTP=VP(7)
TUL=400.
TLL=TTP
PUL=120.
DCC=13.63
RETURN
END

Appendix F. Properties Subroutines

```

SUBROUTINE PROPS(PP,DD,TT)
C THE 32 TERM EQUATION OF STATE, INPUT IS DENSITY(MOLES/L),
C TEMPERATURE(K), OUTPUT (PP) IS PRESSURE(MPA),OR DP/DD IN
C LITER-MPA/MOLE OR DP/DT MPA/K OR S,H,OR CV AT ONE LIMIT OF
C INTEGRATION
  DIMENSION X(33)
  DIMENSION B(33),G(32),VP(9)
  EQUIVALENCE (B,X)
  COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TTP,TUL,TLL,PUL,DCC
  COMMON/1/B
  DATA(ID=1)
  DATA(IZ=1)
1 CONTINUE
  IF(IZ.LE.0)GO TO 2
  IZ=0
2 CONTINUE
  D=DD
  P=PP
  T=TT
  GM=GAMMA
  D2=D*D
  D3=D2*D
  D4=D3*D
  D5=D4*D
  D6=D5*D
  D7=D6*D
  D8=D7*D
  D9=D8*D
  D10=D9*D
  D11=D10*D
  D12=D11*D
  D13=D12*D
  TS=SQRT (T)
  T2=T*T
  T3=T2*T
  T4=T3*T
  T5=T4*T
  F=EXP (GM*D2)
  GO TO (100,200,300,400,500,600,700),K
  ENTRY PRESS
C  ENTRY FOR PRESSURE, INPUT IS DENSITY
C  AND TEMP. IN MOL/L AND K, OUTPUT IS IN MPA.
  K=1
  GO TO 1
100 CONTINUE
  B( 1)=D2*T
  B( 2)=D2*TS
  B( 3)=D2
  B( 4)=D2/T
  B( 5)=D2/T2
  B( 6)=D3*T
  B( 7)=D3
  B( 8)=D3/T
  B( 9)=D3/T2
  B(10)=D4*T
  B(11)=D4
  B(12)=D4/T
  B(13)=D5
  B(14)=D6/T
  B(15)=D6/T2
  B(16)=D7/T
  B(17)=D8/T

```

```

B(18)=D8/T2
B(19)=D9/T2
B(20)=D3*F/T2
B(21)=D3*F/T3
B(22)=D5*F/T2
B(23)=D5*F/T4
B(24)=D7*F/T2
B(25)=D7*F/T3
B(26)=D9*F/T2
B(27)=D9*F/T4
B(28)=D11*F/T2
B(29)=D11*F/T3
B(30)=D13*F/T2
B(31)=D13*F/T3
B(32)=D13*F/T4
IF(ID.GT.0)GO TO 102
B(33)=P-R*D*T
RETURN
102 P=0
M=32
DO 101 I=1,M
101 P=P+B(I)*G(I)
P=P+R*D*T
PP=P
RETURN
ENTRY DPDD
C PARTIAL OF PRESSURE WITH RESPECT TO
C DENSITY - SEE PRESSURE
C ENTRY FOR UNITS
K=2
GO TO 1
200 CONTINUE
F1=2.00*F*GM*D
F21=3.000*F*D2 +F1*D3
F22=5.000*F*D4 +F1*D5
F23=7.000*F*D6 +F1*D7
F24=9.000*F*D8 +F1*D9
F25=11.00*F*D10+F1*D11
F26=13.00*F*D12+F1*D13
B( 1)=2.00*D*T
B( 2)=2.00*D*TS
B( 3)=2.00*D
B( 4)=2.00*D/T
B( 5)=2.00*D/T2
B( 6)=3.00*D2*T
B( 7)=3.00*D2
B( 8)=3.00*D2/T
B( 9)=3.00*D2/T2
B(10)=4.00*D3*T
B(11)=4.00*D3
B(12)=4.00*D3/T
B(13)=5.00*D4
B(14)=6.00*D5/T
B(15)=6.00*D5/T2
B(16)=7.00*D6/T
B(17)=8.00*D7/T
B(18)=8.00*D7/T2
B(19)=9.00*D8/T2
B(20)=F21/T2
B(21)=F21/T3
B(22)=F22/T2
B(23)=F22/T4
B(24)=F23/T2
B(25)=F23/T3
B(26)=F24/T2

```

```

B(27)=F24/T4
B(28)=F25/T2
R(29)=F25/T3
B(30)=F26/T2
B(31)=F26/T3
B(32)=F26/T4
M=32
IF(ID.GT.0)GO TO 202
B(33)=P-R*T
RETURN
202 P=0
DO 201 I=1,M
201 P=P+B(I)*G(I)
P=P+R*T
PP=P
RETURN
ENTRY DPDT
C PARTIAL OF PRESSURE WITH RESPECT
C TO TEMPERATURE - SEE PRESSURE
C ENTRY FOR UNITS
K=3
GO TO 1
300 CONTINUE
X( 1)=D2
X( 2)=D2/(2.00*TS)
X( 3)=0
X( 4)=-D2/T2
X( 5)=-2.00*D2/T3
X( 6)=D3
X( 7)=0
X( 8)=-D3/T2
X( 9)=-2.00*D3/T3
X(10)=D4
X(11)=0
X(12)=-D4/T2
X(13)=0
X(14)=-D6/T2
X(15)=-2.00*D6/T3
X(16)=-D7/T2
X(17)=-D8/T2
X(18)=-2.00*D8/T3
X(19)=-2.00*D9/T3
X(20)=-2.00*D3*F/T3
X(21)=-3.00*D3*F/T4
X(22)=-2.00*D5*F/T3
X(23)=-4.00*D5*F/T5
X(24)=-2.00*D7*F/T3
X(25)=-3.00*D7*F/T4
X(26)=-2.00*D9*F/T3
X(27)=-4.00*D9*F/T5
X(28)=-2.00*D11*F/T3
X(29)=-3.00*D11*F/T4
X(30)=-2.00*D13*F/T3
X(31)=-3.00*D13*F/T4
X(32)=-4.00*D13*F/T5
IF(ID.GT.0)GO TO 302
X(33)=PP-R*D
RETURN
302 P=0
DO 301 I=1,32
301 P=P+G(I)*X(I)
PP=P+R*D
RETURN
ENTRY DSDN
C PARTIAL OF ENTROPY WITH

```

```

C RESPECT TO THE G COEFFICIENTS
K=4
GO TO 1
400 CONTINUE
C S=S0-R*LOGF(D*R*T/PO)+(DSDN(D)-DSDN(0))*1000. +CPOS(T)
G1=F/(2.00*GM)
G2=(F*D2-2.00*G1)/(2.00*GM)
G3=(F*D4-4.00*G2)/(2.00*GM)
G4=(F*D6-6.00*G3)/(2.00*GM)
G5=(F*D8-8.00*G4)/(2.00*GM)
G6=(F*D10-10.00*G5)/(2.00*GM)
X( 1)=-D
X( 2)=-D/(2.00*TS)
X( 3)=0.D0
X( 4)=+D/T2
X( 5)=2.00*D/T3
X( 6)=-D2/2.00
X( 7)=0.D0
X( 8)=D2/(2.00*T2)
X( 9)=D2/T3
X(10)=-D3/3.00
X(11)=0.D0
X(12)=D3/(3.00*T2)
X(13)=0.D0
X(14)=D5/(5.00*T2)
X(15)= 2.00*D5/(5.00*T3)
X(16)=D6/(6.00*T2)
X(17)=D7/(7.00*T2)
X(18)=2.00*D7/(7.00*T3)
X(19)=D8/(4.00*T3)
X(20)=2.00*G1/T3
X(21)=3.00*G1/T4
X(22)=2.00*G2/T3
X(23)=4.00*G2/T5
X(24)=2.00*G3/T3
X(25)=3.00*G3/T4
X(26)=2.00*G4/T3
X(27)=4.00*G4/T5
X(28)=2.00*G5/T3
X(29)=3.00*G5/T4
X(30)=2.00*G6/T3
X(31)=3.00*G6/T4
X(32)=4.00*G6/T5
IF(ID.GT.0)GO TO 402
RETURN
402 P=0
DO 401 I=1,32
401 P=P+G(I)*X(I)
PP=P
RETURN
ENTRY DUDN
C TERMS NEEDED FOR ENTHALPY CALCULATION
K=5
GO TO 1
500 CONTINUE
C H=H0+(T*DSDN(D)-DSDN(0))*1000.+(DUDN(D-DUDN(0))*1000.+CPOH(T)
C +(P/D-P*T)*1000.
G1=F/(2.00*GM)
G2=(F*D2-2.00*G1)/(2.00*GM)
G3=(F*D4-4.00*G2)/(2.00*GM)
G4=(F*D6-6.00*G3)/(2.00*GM)
G5=(F*D8-8.00*G4)/(2.00*GM)
G6=(F*D10-10.00*G5)/(2.00*GM)
X( 1)=D*T
X( 2)=D*TS

```

```

X( 3)=D
X( 4)=D/T
X( 5)=D/T2
X( 6)=D2*T/2.00
X( 7)=D2/2.00
X( 8)=D2/(2.00*T)
X( 9)=D2/(2.00*T2)
X(10)=D3*T/3.00
X(11)=D3/3.00
X(12)=D3/(3.00*T)
X(13)=D4/4.00
X(14)=D5/(5.00*T)
X(15)=D5/(5.00*T2)
X(16)=D6/(6.00*T)
X(17)=D7/(7.00*T)
X(18)=D7/(7.00*T2)
X(19)=D8/(8.00*T2)
X(20)=G1/T2
X(21)=G1/T3
X(22)=G2/T2
X(23)=G2/T4
X(24)=G3/T2
X(25)=G3/T3
X(26)=G4/T2
X(27)=G4/T4
X(28)=G5/T2
X(29)=G5/T3
X(30)=G6/T2
X(31)=G6/T3
X(32)=G6/T4
IF(ID.GT.0)GO TO 502
RETURN
502 P=0
DO 501 I=1,32
501 P=P+G(I)*X(I)
PP=P
RETURN
ENTRY TDSDT
C TEMP. TIMES THE PARTIAL OF
C ENTROPY WITH RESPECT TO TEMP.
K=6
GO TO 1
600 CONTINUE
C CV=CVO+(TDSDN()-TDSDN(D))*1000.
G1=F/(2.00*GM)
G2=(F*D2-2.00*G1)/(2.00*GM)
G3=(F*D4-4.00*G2)/(2.00*GM)
G4=(F*D6-6.00*G3)/(2.00*GM)
G5=(F*D8-8.00*G4)/(2.00*GM)
G6=(F*D10-10.00*G5)/(2.00*GM)
X(1)=0
X( 2)=-D/(4.00*TS)
X(3)=0
X( 4)=2.00*D/T2
X( 5)=6.00*D/T3
X(6)=0
X(7)=0
X( 8)=D2/T2
X( 9)=3.00*D2/T3
X(10)=0
X(11)=0
X(12)=(2.00*D3)/(3.00*T2)
X(13)=0
X(14)=(2.00*D5)/(5.00*T2)
X(15)=(6.00*D5)/(5.00*T3)

```

```

X(16)=D6/(3.00*T2)
X(17)=(2.00*D7)/(7.00*T2)
X(18)=(6.00*D7)/(7.00*T3)
X(19)=(3.00*D8)/(4.00*T3)
X(20)=6.000*G1/T3
X(21)=12.00*G1/T4
X(22)=6.000*G2/T3
X(23)=20.00*G2/T5
X(24)=6.000*G3/T3
X(25)=12.00*G3/T4
X(26)=6.000*G4/T3
X(27)=20.00*G4/T5
X(28)=6.000*G5/T3
X(29)=12.00*G5/T4
X(30)=6.000*G6/T3
X(31)=12.00*G6/T4
X(32)=20.00*G6/T5
IF(ID.GT.0)GO TO 602
RETURN
602 P=0
DO 601 I=1,32
601 P=P+G(I)*X(I)
PP=P
RETURN
ENTRY DP2D2
C SECOND PARTIAL OF PRESSURE WITH
C RESPECT TO DENSITY SQUARED
K=7
GO TO 1
700 CONTINUE
F1=2.*F*GM*D
F12=2.*F1*GM*D+2.*F*GM
F212=3.*F1*D2+3.*2.*D*F+F12*D3+F1*3.*D2
F222=5.*F1*D4 +5.*4.*D3*F+5.*D4*F1+F12*D5
F232=7.*F1*D6+7.*6.*D5*F+7.*D6*F1+F12*D7
F242=9.*F1*D8+9.*8.*D7*F+9.*D8*F1+F12*D9
F252=11.*F1*D10+10.*11.*D9*F+11.*D10*F1+F12*D11
F262=13.*F1*D12+13.*12.*D11*F+13.*D12*F1+F12*D13
B(1)=2.*T $ B(2)=2.*TS $ B(3)=2.
B(4)=2./T $ B(5)=2./T2 $ B(6)=6.*D*T
B(7)=6.*D $ B(8)=6.*D/T $ B(9)=6.*D/T2
B(10)=12.*D2*T $ B(11)=12.*D2 $ B(12)=12.*D2/T
B(13)=20.*D3 $ B(14)=30.*D4/T $ B(15)=30.*D4/T2
B(16)=42.*D5/T $ B(17)=56.*D6/T $ B(18)=56.*D6/T2
B(19)=72.*D7/T2 $ B(20)=F212/T2 $ B(21)=F212/T3
B(22)=F222/T2
B(23)=F222/T4 $ B(24)=F232/T2 $ B(25)=F232/T3
B(26)=F242/T2 $ B(27)=F242/T4 $ B(28)=F252/T2
B(29)=F252/T3 $ B(30)=F262/T2 $ B(31)=F262/T3
B(32)=F262/T4
M=32
IF(ID.GT.0)GO TO 702
B(33)=PP
RETURN
702 P=0
DO 701 I=1,M
701 P=P+B(I)*G(I)
PP=P
RETURN
END

C
C FUNCTION VPN(TT)
C CALCULATES VAPOR PRESSURE(MPA), INPUT IS TEMP(K).

```

```

DIMENSION G(32),VP(9)
COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TPP,TUL,TLL,PUL,DCC
T=TT
X=(1.-VP(7)/T)/(1.-VP(7)/VP(8))
VPN=VP(9)*EXP (VP(1)*X+VP(2)*X*X+VP(3)*X**3+VP(4)*X**4+VP(5)*X+
1*(1.-X)**VP(6))
RETURN
END

C
FUNCTION FINDTV(POBS)
C ITERATES VAPOR PRESS EQN TO FIND TEMP(K), FOR INPUT OF PRESS(MPA).
C GIVEN AN INPUT PRESSURE(MPA)
COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TPP,TUL,TLL,PUL,DCC
DIMENSION G(32),VP(9)
T=VP(8)
DO 7 I=1,10
P=VPN(T)
IF(ABS (P-POBS)-.000001*POBS)8,8,6
6 CONTINUE
CORR=(POBS-P)/DPDTVP(T)
7 T=T+CORR
8 CONTINUE
FINDTV=T
RETURN
END

C
FUNCTION CV(D,T)
C CALCULATES CV(J/(MOL*K)). INPUT DENS(MOL/L) AND TEMP(K).
DATA(R=8.31434)
DD=D
TT=T
CALL TDSDT(CD,DD,TT)
DD=0
CALL TDSDT(CO,DD,TT)
CV=CPI(TT)+(CO-CD)*1000.
CV=CV-R
RETURN
END

C
FUNCTION FIND D(P,T)
C ITERATES EQUATION OF STATE FOR DENSITY(MOL/L), FOR GIVEN PRESSURE(MPA) AND
C TEMPERATURE(K). IF ITERATION FAILS TRY USING FUNCTION FIND M.
DIMENSION G(32),VP(9)
COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TPP,TUL,TLL,PUL,DCC
TT=T
IF(TT.GT.VP(8)*.99999)GO TO 100
IF( P.GT.VPN(TT))GO TO 101
DD=SATV(TT)
GO TO 102
100 PC=PCC
X=(1.1/(9.*PC))*P+.7/9.
DD=P/(R*T*X)
IF(P/PC.GT.20..AND.T/VP(8).LT.2.5)DD=DTP
GO TO 102
101 DD=SATL(TT)
102 CONTINUE
DO 10 I=1,50
IF(DD.LE.0.0.OR.DD.GT.50.)GO TO 11
CALL PRESS(PP,DD,TT)

```

```

IF(PP.LE.0.0)GO TO 11
P2=PP
IF(ABS (P-P2)-1.E-7*P)20,20,1
1 CALL DPDD(PP,DD,TT)
DP=PP
CORR=(P2-P)/DP
IF(ABS (CORR)-1.E-7*DD)20,20,10
10 DD=DD-CORR
11 CALL REGULA(P,DD,T)
20 FIND D=DD
RETURN
END

C
C      SUBROUTINE REGULA(PI,DD,TT)
C      ITERATES EQN OF STATE FOR DENSITY WHEN SUBPROG FINDD FAILS.
      DIMENSION G(32),VP(9)
      COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TTT,TUL,TLL,PUL,DCC
      T=TT
      P=PI
      D2=0
      IF(T.LT.TCC)GO TO 10
      D0=DCC*TCC/T
      GO TO 20
10  PP=VPN(T)
      IF(P.GT.PP)GO TO 15
      D0=SATV(T)
      DO 11 I=1,150
      CALL PRESS(PO,D0,T)
      IF(PO.GE.P)GO TO 12
11  D0=D0+.0001*D0
      GO TO 42
12  D1=D0
13  CALL PRESS(P1,D1,T)
      IF(P1.LT.P)GO TO 14
      IF(D1.LE..1*PTP)GO TO 42
      D0=D1
      Z=(P1-P)/P
      IF(Z.LT..1)Z=.1
      IF(Z.GT..9)Z=.9
      D1=D1-Z*D1
      GO TO 13
14  CALL PRESS(PO,D0,T)
      DO 140 I=1,50
      D=D1
      P3=P1
      IF(ARS(P-P1).LT..00001*P)GO TO 40
      P2=P-P1
      D1=D1+(D1-D0)*P2/(P1-PO)
      IF(ABS(D-D1).LE..00001*D)GO TO 40
      IF(ABS(P-P1).LT..005*P)D2=FIND M(P,T,D1)
      IF(D2.GT.0.0.AND.D2.LT.50.)D1=D2
      D2=0
      CALL PRESS(P1,D1,T)
      IF(PO.GT.P.AND.P1.GT.P)GO TO 120
      IF(PO.LT.P.AND.P1.LT.P)GO TO 120
      GO TO 140
120 PO=P3
      DO=D
140 CONTINUE
      GO TO 41
15  D0=SATL(T)
      DO 16 I=1,10
      CALL PRESS(PO,D0,T)

```

```

    IF(P0.LE.P)GO TO 17
16 D0=D0-.0001*D0
    GO TO 42
17 D1=D0
18 CALL PRESS(P1,D1,T)
    IF(D1.GE.50.)GO TO 42
    IF(P1.GT.P)GO TO 14
    D0=D1
    Z=(P-P1)/P
    Z=Z*10
    IF(T/TCC.LT..6)Z=1.
    IF(Z.LT.1.)Z=1.
    IF(Z.GT.9.)Z=9.
    D1=D1+.01*D1*Z
    GO TO 18
20 CALL PRESS(P0,D0,T)
    IF(P.LE.P0)GO TO 30
    D1=D0
21 CALL PRESS(P1,D1,T)
    IF(P1.GE.P)GO TO 14
    IF(D1.GE.50.)GO TO 42
    D0=D1
    Z=(P-P1)/P
    Z=Z*10
    IF(Z.LT.1.)Z=1
    IF(Z.GT.9.)Z=9
    D1=D1+.1*D1*Z
    GO TO 21
30 D1=D0
31 CALL PRESS(P1,D1,T)
    IF(P1.LE.P)GO TO 14
    IF(D1.LE..1*PTP)GO TO 42
    D0=D1
    Z=(P1-P)/P
    Z=Z*10
    IF(Z.LT.1.)Z=1
    IF(Z.GT.9.)Z=9
    D1=D1-.1*D1*Z
    GO TO 31
40 DD=D1

```

```

    RETURN
41 PRINT 101,P,T,D
102 FORMAT(* REGULA FAILED AT P=*,F7.2,* AND T=*,F7.2)
101 FORMAT(* DENSITY ITTERATION FAILED AT P=*,F7.2,* AND T=*,F7.2,
1/* DENSITY RETURNED IS*,E17.8)
    RETURN
42 PRINT 102,P,T
    RETURN
END

```

```

C
C      FUNCTION CP(D,T)
C      CALCULATES CP(J/(MOL*K)).  INPUT DENS(MOL/L), TEMP(K).
C      CVEE=CV(D,T)
C      CALL DPDT(DPT,D,T)
C      CALL DPDD(DPD,D,T)
C      CP=CVEE+(T/(D**2)*(DPT**2)/DPD)*1000.
C      RETURN
C      END

```

```

FUNCTION DPDTVP(TT)
C CALCULATES THE DERIVATIVE OF PRESSURE WITH RESPECT TO TEMPERATURE
C AT SATURATION. INPUT IS TEMP(K), OUTPUT IS DPDT(MPA/K).
COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TTT,TUL,TLL,PUL,DCC
DIMENSION G(32),VP(9)
T=TT
IF(TT.GT.VP(8))GO TO 1
X=(1.-VP(7)/T)/(1.-VP(7)/VP(8))
DXDT=(VP(7)/T**2)/(1.-VP(7)/VP(8))
DPDT=VP(1)*DXDT+2.*VP(2)*X*DXDT+VP(3)*3.*X**2*DXDT+VP(5)*
1((1.-X)**VP(6))*DXDT+VP(5)*X*((1.-X)**(VP(6)-1.))*VP(6)*(-DXDT)
DPDT=DPDT*VPN(T)
DPDTVP=DPDT
RETURN
1 DPDTVP=0
RETURN
END

```

```

C
FUNCTION FIND M(P,T,DD)
C SOLVES FOR DENSITY(MOL/L) BY ITERATION. INPUT IS PRESSURE(MPA),
C TEMPERATURE(K), AND A STARTING VALUE OF DENSITY. THIS FCN IS AN
C ALTERNATIVE FOR FUNCTION FIND D.
TT=T
DO 10 I=1,50
CALL PRESS(PP,DD,TT)
P2=PP
IF(ABS (P-P2)-1.E-7*P)20,20,1
1 CALL DPDD(PP,DD,TT)
DP=PP
CORR=(P2-P)/DP
D=DD
IF(ABS (CORR)-1.E-7*D)20,20,10
10 DD=DD-CORR
FIND M=0
RETURN
20 FIND M=DD
RETURN
END

```

```

C
FUNCTION ENTHAL(P,D,T)
C RETURNS ENTHALPY(J/MOL) FOR AN INPUT OF PRESSURE(MPA) AND DENSITY(MOL/L),
C AND TEMPERATURE(K).
R= .00831434
DD=D
TT=T
CALL DSDN(SD,DD,TT)
CALL DUDN(UD,DD,TT)
DD=0
CALL DSDN(S0,DD,TT)
CALL DUDN(U0,DD,TT)
ENTHAL=T*(SD-S0)*1000.+(UD-U0)*1000.+HI(T)+(P/D-R*T)*1000.
RETURN
END

```

```

C
FUNCTION ENTROP(D,T)
C CALCULATES ENTROPY(J/(MOL-K), FROM INPUT OF DENSITY(MOL/L) AND TEMP(K).
R= .00831434
P0= .101325
DD=D

```

```

TT=T
CALL DSDN(SD,DD,TT)
DD=0
CALL DSDN(S0,DD,TT)
ENTROP=(SD-S0)*1000.-R*ALOG(D*R*T/PO)*1000.+SI(T)
RETURN
END

C
FUNCTION SATL(TT)
C CALCULATES DENSITY(MOL/L) OF SATURATED LIQUID. INPUT IS TEMP(K).
DIMENSION A(20)
DIMENSION G(32),VP(9)
COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TTP,TUL,TLL,PUL,DCC
COMMON/SATC/A,DTPV
T=TT
K=14
KK=7
GO TO 10
ENTRY SATV
K=1
KK=13
T=TT
10 IF(T.GE.TCC*.99999)GO TO 20
ITT=TCC
IF(ITT+1-T.LT.1.)T=ITT
X=(T-TCC)/(TTP-TCC)
D=A(K)*ALOG(X)
DO 11 I=2,KK
K=K+1
MM=I
IF(MM.GE.5)MM=MM+1
11 D=D+A(K)*(1.-X**((MM-5)/3.))
IF(K.LT.14)GO TO 12
D=DCC+EXP(D)*(DTP-DCC)
GO TO 13
12 D=DCC+EXP(D)*(DTPV-DCC)
13 SATL=D
IF(ITT+1-TT.LT.1.)SATL=D-(D-DCC)*(TT-T)
RETURN
20 DSATL=DCC
RETURN
END

C
FUNCTION SOUND(D,T)
C CALCULATES SPEED OF SOUND(M/S). INPUT IS DENSITY(MOL/L) AND TEMP(K).
COMMON/CRIT/ W, EOK, RM, TC, DC, X , PC, SIG
CALL DPDD(DP,D,T)
SOUND=((CP(D,T)/CV(D,T))*DP*1000000./W)**.5
RETURN
END

C
FUNCTION VISC(DD,T)
C CALCULATES VISCOSITY(MICRO PA*S). INPUT IS DENSITY(MOL/L) AND TEMP(K).
COMMON/CRIT/ EM, EOK, RM, TC, DC, X , PC, SIG
D=DD*EM/1000.
VISC=DILV(T)+FDCV(D,T)+EXCESV(D,T)
RETURN
END

```

```

C      FUNCTION THERM(DD,T)
C  RETURNS THERMAL CONDUCTIVITY(W/(M*K)). INPUT IS DENSITY(MOL/L), TEMP(K).
  COMMON/HAN/CR,TCI
  COMMON/ISP/N,NW,NWW
  COMMON/CRIT/ EM, EOK, RM, TC, DC, X , PC, SIG
  D=DD*EM/1000.
  CR=CRITC(D,T)
  THER=DILT(T)+FDCT(D,T)+EXCEST(D,T)+CR
  TCI=THER-CR
  THERM=THER
  RETURN
  END

C      FUNCTION EXCESV(D,T)
C  CALCULATES EXCESS VISCOSITY
  COMMON/DATA1/GV,GT,FV,FT,EV,ET
  DIMENSION GV(9),GT(9),FV(4),FT(4),EV(8),ET(8)
  R2=D**(.5)*((D-EV(8))/EV(8))
  R=D**(.1)
  X=EV(1)+EV(2)*R2+EV(3)*R+EV(4)*R2/(T*T)+EV(5)*R/T**(.5)+EV(6)/T
  1+EV(7)*R2/T
  X1=EV(1)+EV(6)/T
  EXCESV= EXP(X)- EXP(X1)
  RETURN
  ENTRY EXCEST
C  CALCULATES EXCESS THERMAL CONDUCTIVITY
  R2=D**(.5)*((D-ET(8))/ET(8))
  R=D**(.1)
  X=ET(1)+ET(2)*R2+ET(3)*R+ET(4)*R2/(T*T)+ET(5)*R/T**(.5)+ET(6)/T
  1+ET(7)*R2/T
  X1=ET(1)+ET(6)/T
  EXCESV= EXP(X)- EXP(X1)
  RETURN
  END

C      FUNCTION FDCV(D,T)
C  FIRST DENSITY CORRECTION FOR VISC AND THERMAL COND.
  COMMON/DATA1/GV,GT,FV,FT,EV,ET
  DIMENSION GV(9),GT(9),FV(4),FT(4),EV(8),ET(8)
  FDCV=(FV(1)+FV(2)*(FV(3)-ALOG(T/FV(4)))**2)*D
  RETURN
  ENTRY FDCT
  FDCV=(FT(1)+FT(2)*(FT(3)-ALOG(T/FT(4)))**2)*D
  RETURN
  END

C      FUNCTION CRITC(D,T)
C  CALCULATES CRITICAL ENHANCEMENT FOR THERM. COND.
C  INPUT UNITS ARE G/CC, K, OUTPUT IS W/(M*K).
  COMMON/CRIT/ EM, EOK, RM, TC, DC, X , PC, SIG
  COMMON/CHECK/DELD,DELT,DSTAR,TSTAR
  COMMON/HJM/EPSI,CPCV,RRR,AKT
  COMMON/ISP/N,NW,NWW
  AV=6.0225E+23 $ BK=1.38054E-16
  DELD=ABS (D-DC)/DC $ DELT=ABS (T-TC)/TC
C  CALCULATE DISTANCE PARAMETER
  R=(RM**2.5)*(D**0.5)*(AV/EM)**0.5
  R=R*(EOK**0.5)*X/(T**0.5)

```

```

      RRR=R
C   GENERAL EQUATION
      DX=D*1000.0/EM
C   DX IN MOL/L, D IN G/CM3.
      CALL DPDT(DPT,DX,T)
C   DPDT IN MPA/K.
      DPT=DPT*1.0E+7
C   DPDT NOW IN DYNES/(CM2*K)
      CALL DPDD(DPD,DX,T)
C   DPDD IN L*MPA/MOL.
      DPD=DPD*1.0E+7*1000./EM
C   DPDD NOW IN DYNE*CM/G.
      IF( DPD.LT.0.0) DPD=1.0
94  VIS=VISC(DX,T)*(1.0E-05)
C   VISCOSITY NOW IS G/(CM*S).
      IF(DELD.EQ.0.25. OR. DELD.LT. 0.25) 8,10
8   IF(DELT.EQ.0.025. OR. DELT.LT.0.025 ) 9, 10
9   COMPRES=SENG(D,T)
      GO TO 12
10  COMPRES=1.0/(D*DPD)**0.5
12  EX=BK*T**2*(DPT**2)*COMPRES
      EXB=R*((BK*T)**0.5)*(D**0.5)*((AV/EM)**0.5)
      CRIT=EX/(EXB*6.0*3.14159*VIS)
C   THERMAL COND, CRIT, IS IN ERG/(CM*SEC*K)
C   PUT IN DAMPING FACTOR
      BDD=((D-DC)/DC)**4
      BTT=((T-TC)/TC)**2
      BXX= -18.66*RTT - 4.25*RDD
      IF(BXX.LT.-1.E+2) BXX= -1.E+2
      FACT= EXP( BXX )
C   FACT=EXP (-18.66*BTT - 4.25*BDD)
      DELC=CRIT*FACT
      CRITC=DELC/100000.
C   THERMAL COND, CRITC, IS NOW IN W/(M*K)
      AKT=COMPRES*COMPRES
      EPSI=R*R*BK*T*(AV*D/EM)*AKT
      EPSI=EPSI**0.5
C   CALC CP-CV
      CPCV=T*(DPT**2)*AKT/D
      RETURN
      END

C
C   FUNCTION SENG(D,T)
C   SCALED EQUATION OF STATE FOR CRITICAL REGION
      COMMON/CRIT/ EM, EOK, RM, TC, DC, X , PC, SIG
      COMMON/SEN/BETA,XO,DELTA,E1, E2, AGAM
      COMMON/CHECK/DELD,DELT,DSTAR,TSTAR
      DSTAR= D/DC $ TSTAR=T/TC
      BETO=1./BETA
      XX=DELT/DELD**BETO
      AG=AGAM-1.0
      BET2= 2.0*BETA
      AGR=AG/BET2
      DEL1=DELTA-1.0
      AGBB=(AG-BET2)/BET2
      XXO=(XX+ XO)/XO
      XXB=XXO**BET2
      BRAK=1.0 + E2*XXB
      BRAK1=BRAK**AGB
      H=E1*XXO*BRAK1
      HPRIM=(E1/XO)*BRAK1 + (AG/XO)*E1*E2*(XXB)*(BRAK**AGBB)
      RCOM=(DELD**DEL1)*(DELTA*H - (XX/BETA)*HPRIM )
      RCOMP=1.0/(RCOM*DSTAR**2)

```

```

RCM=RCOMP/(PC*1.0E+7)
C RCM IN CM2/DYNE, PC IN MPa
RCM=RCM**0.5
C
SENG=RCM
RETURN
END

C
FUNCTION DILV(T)
C DILUTE GAS VISCOSITY AND THERMAL CONDUCTIVITY.
COMMON/DATA1/GV,GT,FV,FT,EV,ET
DIMENSION GV(9),GT(9),FV(4),FT(4),EV(8),ET(8)
SUM=0
TF=T**(.1./3.)
TFF=T**(-4./3.)
DO 10 I=1,9
TFF=TFF*TF
10 SUM=SUM+GV(I)*TFF
DILV=SUM
RETURN
ENTRY DILT
TF=T**(.1./3.)
TFF=T**(-4./3.)
SUM=0
DO 20 I=1,9
TFF=TFF*TF
20 SUM=SUM+GT(I)*TFF
DILV=SUM
RETURN
END

C
FUNCTION FIND P(D,T)
DIMENSION G(32),VP(9)
COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TTP,TUL,TLL,PUL,DCC
DD=D
TT=T
IF(TT.LT.TCC)GO TO 10
1 CALL PRESS(PP,DD,TT)
FIND P=PP
RETURN
10 P=VPN(TT)
DV=FIND D(P-.0001,TT)
DL=FIND D(P+.0001,TT)
IF(DD.LE.DV.OR.DD.GE.DL)GO TO 1
PRINT 100,DV,DL,DD
CALL PRESS(PP,DV,TT)
FIND P=PP
D=DV
RETURN
100 FORMAT(* THE STATE POINT YOU HAVE SPECIFIED CORRESPONDS TO A *
1/* DENSITY IN THE LIQUID VAPOR COEXISTENCE REGION*
2/* THE DENSITY OF THE SATURATED VAPOR IS *,F6.4,* MOLES/LITER*
3/* THE DENSITY OF THE SATURATED LIQUID IS *,F8.4,* MOLES/LITER*
4/* AND THE INPUT DENSITY IS *,F8.4,* MOLES/LITER*
5/* SATURATED VAPOR IS ASSUMED*)
END

C
FUNCTION FINDT(P,D)
C RETURNS TEMPERATURE(K), FROM THE 32-TERM MBWR EQN OF STATE.

```

```

C INPUT IS PRESSURE(MPA) AND DENSITY(MOL/L).
DIMENSION G(32),VP(9)
COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TTP,TUL,TLL,PUL,DCC
PP=P
DD=D
IF(P.GE.PCC)GO TO 1
TSAT=FINDTV(PP)
DV=FIND D(PP-.00001,TSAT)
DL=FIND D(PP+.0001,TSAT)
IF(DD.GT.DV.AND.DD.LT.DL)GO TO 30
TT=TSAT
GO TO 2
1 TT=TCC
2 DO 10 I=1,10
  CALL PRESS(P2,DD,TT)
  IF(ABS(PP-P2)-1.E-7*PP)20,20,11
11 CALL DPDT(DP,DD,TT)
  CORR=(P2-PP)/DP
  IF(ABS(CORR)-1.E-5)20,20,10
10 TT=TT-CORR
20 FINDT=TT
  RETURN
30 FINDT=TSAT
  D=DV
  PRINT 100,DV,DL,DD
100 FORMAT(* THE STATE POINT YOU HAVE SPECIFIED CORRESPONDS TO*
1/* A DENSITY IN THE LIQUID VAPOR COEXISTENCE REGION*
2/* DENSITY OF THE SATURATED VAPOR IS*,F8.4,* MOLES/LITER*
3/* DENSITY OF THE SATURATED LIQUID IS*,F8.4,* MOLES/LITER*
4/* INPUT DENSITY IS*,F8.4,* MOLES/LITER*
5/* SATURATED VAPOR CONDITIONS ARE ASSUMED*)
  RETURN
END

```

```

C
SUBROUTINE INFO
PRINT 100
100 FORMAT(//* WHEN THE PROGRAM ASKS FOR A FLUID SELECTION, ENTER THE*
1*APPROPRIATE NUMBER.*/* AN INAPPROPRIATE NUMBER WILL TERMINATE*
2* THE PROGRAM. WHEN THE PROGRAM ASKS/*/* FOR A PRESSURE, DENSITY*
3*, AND TEMPERATURE, ENTER ANY TWO OF THE THREE/*/* AND A ZERO FOR*
4* THE THIRD.*/* THE ORDER MUST BE P,D,T, AND ONE OF THE THREE*
5* MUST BE ZERO.*/* IF ALL THREE ARE ZERO THE PROGRAM ASKS FOR A*
6* NEW FLUID.*)
  RETURN
END

```

```

C
FUNCTION DIEL(P,D,T)
C DIELECTRIC CONSTANT. INPUT P(MPA), D(MOL/L) AND T(K).
COMMON/DIEL/BX(6),PX(6)
CM= BX(1)+ BX(2)*D+ BX(3)*D**2+ BX(4)*D**3+ BX(5)*P+ BX(6)*T
DIEL=(1.+2.*D*CM)/(1.-D*CM)
RETURN
END

```

```

FUNCTION CPI(T)
C CALCULATES SPECIFIC HEAT, ENTROPY, AND ENTHALPY FOR THE IDEAL GAS.
C OUTPUT IS IN J/(MOL*K), FOR CP AND S, AND J/MOL FOR H.
C HYDROGEN, (N=1), IS TREATED AS A SPECIAL CASE AS THE COEFF. FOR
C CP ARE IN THREE TEMPERATURE RANGES. T < 40 K, 40 < T < 140 K,
C AND T > 140 K.

```

```

COMMON/CPID/G(11),GH(11),GL(11)
COMMON/ISP/N,NW,NWW
K=1
IF(N.EQ.1) 10,15
10 C=CPO(T)
15 U=G(9)/T
EU=EXP (U)
TS=1./T**4
GO TO (20,40,55),K
20 CPI=G(8)*U*U*EU/(EU-1.)**2
DO 25 I=1,7
TS=TS*T
25 CPI=CPI+G(I)*TS
CPI=CPI*8.31434
RETURN

C
ENTRY SI
K=2
IF(N.EQ.1) 30,35
30 C=CPO(T)
35 GO TO 15
40 CPI=G(8)*(U/(EU-1.)-ALOG(1.-1./EU))
1-G(1)*TS*T/3.-G(2)*TS*T*T/2.-G(3)/T+G(4)*ALOG(T)+G(5)*T+G(6)*T*T/2
2.+G(7)*T**3/3.
CPI=CPI*8.31434+G(11)
RETURN

C
ENTRY HI
K=3
IF(N.EQ.1) 45,50
45 C=CPO(T)
50 GO TO 15
55 CPI=G(8)*U*T/(EU-1.)-G(1)/(2.*T*T)-G(2)/T+G(3)*ALOG(T)+G(4)*T
1+G(5)*T*T/2.+G(6)*T**3/3.+G(7)*T**4/4.
CPI=CPI*8.31434+G(10)
RETURN
END

FUNCTION CPO(T)
C SELECTS PROPER COEFF FOR G(I), AND COMPUTES G(10) AND G(11).
C FOR HYDROGEN ONLY.
COMMON/CPID/G(11),GH(11),GL(11)
TX1=140.
TX2=40.
DO 10 J=1,11
10 G(J)=GH(J)
IF(T.LT.140.) 30,20
20 CPO=1.0
RETURN
30 G(10)=G(10)+GHI(TX1)
G(11)=G(11)+GSI(TX1)
DO 40 J=1,8
40 G(J)=GL(J)
G(10)=G(10)-GHI(TX1)
G(11)=G(11)-GSI(TX1)
IF(T.LT.40.) 60,50
50 CPO=1.0
RETURN
60 G(10)=G(10)+GHI(TX2)
G(11)=G(11)+GSI(TX2)
DO 70 J=1,8
70 G(J)=0.0
G(4)=2.5000315
G(10)=G(10)-GHI(TX2)

```

```

G(11)=G(11)-GSI(TX2)
CPO=1.0
RETURN
END

FUNCTION GHI(T)
COMMON/CPID/G(11),GH(11),GL(11)
1 U=G(9)/T
EU=EXP(U)
GHI=G(8)*U*T/(EU-1.)-G(1)/(2.*T*T)-G(2)/T+G(3)* ALOG(T)+G(4)*T
A +G(5)*T*T/2.+G(6)*T**3/3.+G(7)*T**4/4.
GHI=GHI*8.31434
RETURN
C
ENTRY GSI
U=G(9)/T
EU=EXP(U)
TS=1./T**4
GHI= G(8)*(U/(EU-1.))-ALOG(1.-1./EU))-
A G(1)*TS*T/3.-G(2)*TS*T*T/2.-G(3)/T+G(4)* ALOG(T)+G(5)*T+
B G(6)*T*T/2.+G(7)*T**3/3.
GHI=GHI*8.31434
RETURN
END

SUBROUTINE LIMITS(P,T,IL)
DIMENSION G(32),VP(9)
COMMON/DATA/G,R,GAMMA,VP,DTP,PCC,PTP,TCC,TPP,TUL,TLL,PUL,DCC
COMMON/DIEL/BX(6),PX(6)
IF(P.GT.PUL)GO TO 10
IF(T.GT.TUL.OR.T.LT.TLL)GO TO 12
PM=PMELT(T)
IF(P.GT.PM) GO TO 20
IL=1 $ RETURN
10 PRIMT 11,PUL
11 FORMAT(* THE INPUT PRESSURE IS OUT OF THE RANGE OF THIS EQUATION *
1/* THE RANGE FOR THIS EQUATION IS FROM 0 TO *,F6.0,* BAR*)
IL=0 $ RETURN
12 TLLF= (TLL-273.15)*1.8+32.
TULF= (TUL-273.15)*1.8+32.
PRINT 13, TLL,TUL,TLLF,TULF
13 FORMAT(* THE INPUT TEMPERATURE IS OUT OF RANGE*
A /* THE RANGE FOR THIS EQUATION IS *,F6.2,* K TO *,F6.0,* K*,/,,
B 27X,* OR *,F8.2,* F TO *,F6.0,* F*)
IL=C $ RETURN
20 TM=TMELT(P)
TF=(TM-273.15)*1.8+32.
PRINT 22, TM,TF
22 FORMAT(* SOLID PHASE DETECTED.*,* FOR THIS PRESSURE, TEMP*
A * SHOULD EXCEED *,F8.3,* K, OR*,F9.3,* F*)
IL=0 $ RETURN
END

FUNCTION PMELT(T)
C COMPUTES MELTING PRESSURE(MPA) FOR INPUT TEMPERATURE(K).
COMMON/DIEL/BX(6),PX(6)
COMMON/ISP/N,NW,MW
IF(N.EQ.1) 20,10
10 PMELT= PX(1)+ PX(2)*T**PX(3)
RETURN
20 IF(T.GT.22.) 30,10
30 PMELT= PX(4)+ PX(5)*T**PX(6)

```

```
RETURN
END
```

```
FUNCTION TMELT(P)
C COMPUTES MELTING TEMPERATURE(K) FOR INPUT PRESSURE(MPA)
COMMON/DIEL/BX(6),PX(6)
COMMON/ISP/N,NW,NWW
IF(N.EQ.1) 20,10
10 TMELT=((P-PX(1))/PX(2))**(1./PX(3))
      RETURN
20 IF(P.GT.31.64) 30,10
30 TMELT=((P-PX(4))/PX(5))**(1./PX(6))
      RETURN
END
```

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<p>10. SUPPLEMENTARY NOTES</p> <p><input type="checkbox"/> Document describes a computer program; SF-185, FIPS Software Summary, is attached.</p>			
<p>11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)</p> <p>An interactive FORTRAN IV computer program is given for computing thermophysical properties of argon, ethylene, parahydrogen, nitrogen, nitrogen trifluoride, and oxygen. The program is designed for use with a computer terminal accessing a large computer in an interactive mode. The program provides prompting for selection of several options including: 1) choice of fluid, 2) choice of SI or engineering units, 3) choice of the single phase or liquid-vapor phase, and 4) a table of properties or a single value.</p> <p>Properties are computed for the single phase region from input of two of the variables, temperature, pressure, and density. Values on the liquid-vapor boundary are computed from an entry of temperature or pressure. The program returns values for pressure, temperature, density, internal energy, enthalpy, entropy, specific heats at constant volume and pressure, and sound velocity. Viscosity, thermal conductivity, and dielectric constant are given for some of the fluids. Copies of the programs may be obtained from Office of Standard Reference Data, Attention: Reference Center, National Bureau of Standards, Washington, D.C. 20234.</p>			
<p>12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons) argon; computer programs; density; enthalpy; equation of state; ethylene; hydrogen; nitrogen; nitrogen trifluoride; oxygen; specific heat at constant pressure; specific heat at constant volume.</p>			
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